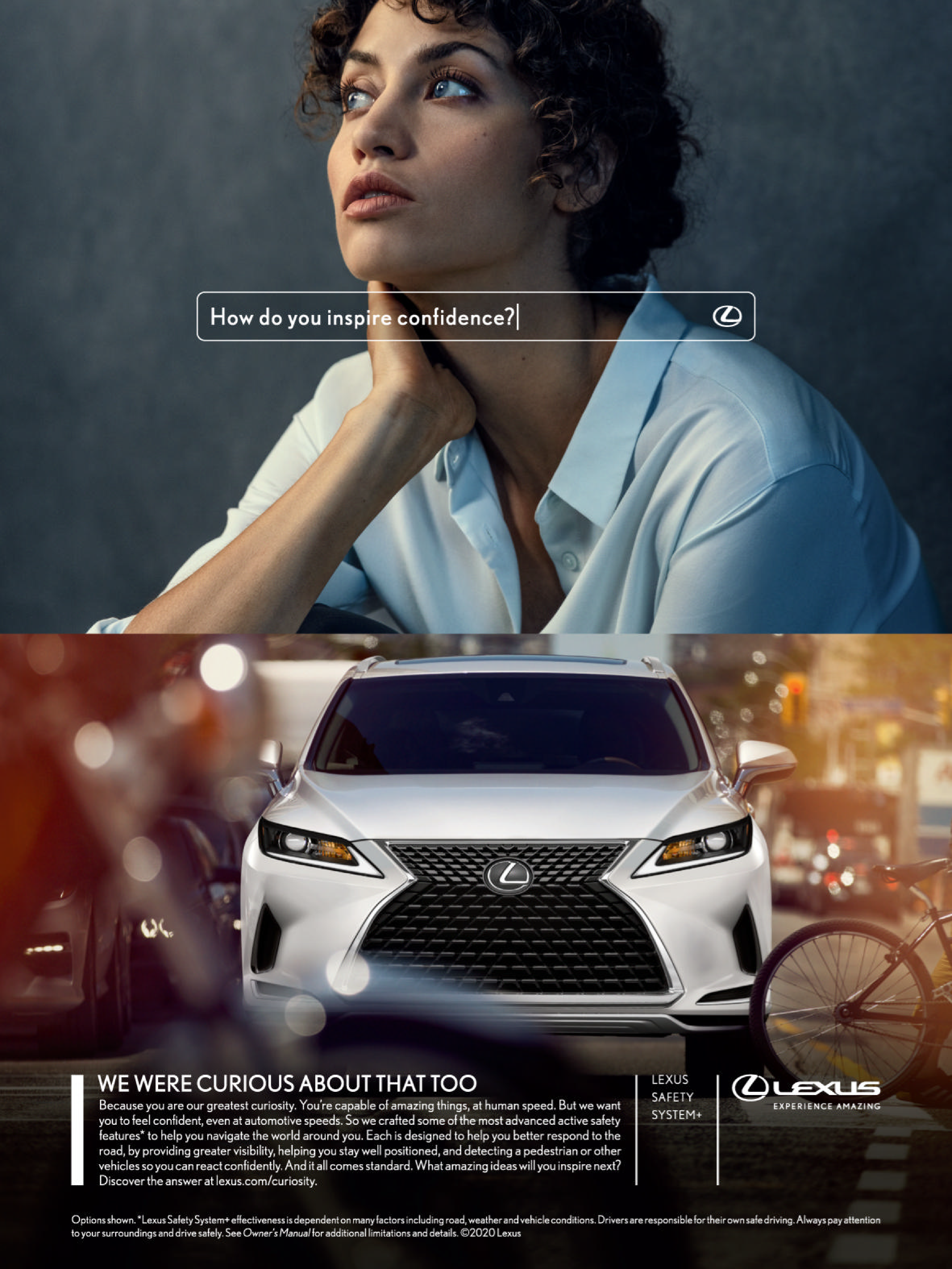


WE WERE CURIOUS ABOUT THAT TOO

Because you are our greatest curiosity. You're capable of amazing things, at human speed. But we want you to feel confident, even at automotive speeds. So we crafted some of the most advanced active safety features* to help you navigate the world around you. Each is designed to help you better respond to the road, by providing greater visibility, helping you stay well positioned, and detecting a pedestrian or other vehicles so you can react confidently. And it all comes standard. What amazing ideas will you inspire next? Discover the answer at lexus.com/curiosity.

LEXUS
SAFETY
SYSTEM+

LEXUS
EXPERIENCE AMAZING

Options shown. *Lexus Safety System+ effectiveness is dependent on many factors including road, weather and vehicle conditions. Drivers are responsible for their own safe driving. Always pay attention to your surroundings and drive safely. See *Owner's Manual* for additional limitations and details. ©2020 Lexus

POPULAR SCIENCE

FALL
2020

the quest to trap dark matter

tracing the origins of outbreaks

where in the world is atlantis?

MYSTERIES

on duty with the bee detective

seven good reasons we see ghosts

earth's secret lairs, revealed

SAVINGS
IS JUST THE START

It starts with getting an additional 15% credit on new and renewal policies effective through October 7th. From there, you'll discover the comfort of 24/7 service with a licensed agent, fast, fair, professional claim handling and why, for over 75 years, GEICO has been the choice of millions of drivers for their insurance needs.

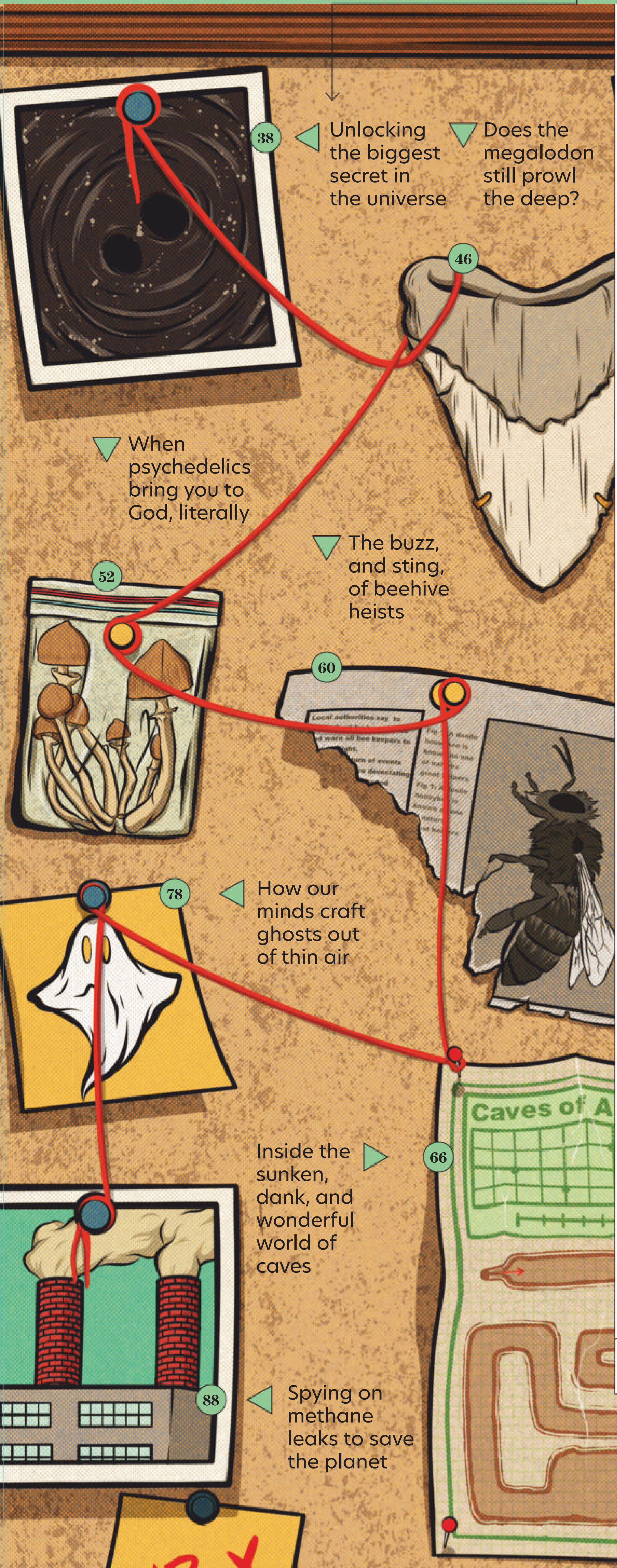
GEICO.COM 1-800-947-AUTO LOCAL AGENT

GEICO®

GEICO Giveback credit available for private passenger auto, motorcycle, and RV policies. Some restrictions apply. Please visit www.geico.com/giveback for more information. Some discounts, coverages, payment plans, and features are not available in all states, in all GEICO companies, or in all situations. GEICO is a registered service mark of Government Employees Insurance Company, Washington, DC 20076; a Berkshire Hathaway Inc. subsidiary. © 2020 GEICO.

CONTENTS

FEATURES



38 Unlocking the biggest secret in the universe

46 Does the megalodon still prowl the deep?

52 When psychedelics bring you to God, literally

60 The buzz, and sting, of beehive heists

66 Inside the sunken, dank, and wonderful world of caves

78 How our minds craft ghosts out of thin air

88 Spying on methane leaks to save the planet

CHARTED

6 Atlantis isn't real, but these disappearing acts are

8 How the mind concocts dreams and nightmares

10 Life found a way, but where exactly did it start?

12 Ethereal etchings of the ancient world

13 Hidden giants circling around our sun

BIG QS

14 The Sherlock Holmes of emerging epidemics

16 Why basic soap is so shockingly effective

16 Curing the seemingly incurable HIV

16 Wait, our immune systems can turn against us?

17 The sneakiest viruses thrive in wildlife

18 Patient zero holds the key to understanding outbreaks

18 The secret sauce for making speedy vaccines

20 Can we prep for the next pandemic?

GOODS

22 Sweet treats that will confuse your taste buds

24 Tangly puzzles to work out your noggin

26 Eerie tricks right out of a magician's top hat

28 Explore rocky depths with these four tools

30 A snoop to glimpse nocturnal animal neighbors

32 Flashlights that brighten up the darkest nights

TALES FROM THE FIELD

95 Are you there, aliens? It's us, Planet Earth

96 Uncovering Picasso's concealed paint strokes

97 Death Valley's boulders move all on their own

98 The art of depicting a deadly germ

98 Your mouth is home to a bacterial cityscape

99 Clouds keep secrets even from the best forecasters

101 Absolutely nobody knows why your kitten purrs

HEAD TRIP

102 Freaky superstitions, free will, and other assorted mysteries to boggle your mind—and make you rethink everything

BEHIND THE COVER

114 Creating and capturing an otherworldly portal

COVER IMAGE BY *THE VOORHES* / ILLUSTRATION BY *MAX ERWIN*

EDITOR'S LETTER

methods, not madness

YEARS BEFORE TRUE-CRIME podcasts sent hordes of listeners-turned-internet-sleuths onto message boards, my brother and I spent our weeknights cross-legged on the living room floor, glued to *Unsolved Mysteries*. Host Robert Stack narrated real-life tales of cold cases, hauntings, and UFO sightings set against archival images, interviews, and re-creations of the events. At its peak, nearly 17 million people tuned in.

NBC canceled the show in 1997 after a 10-year run. But it keeps coming back; networks have reincarnated the series four times. Despite host changes (the recent Netflix reboot eschews one altogether) and production upgrades, much has remained the same—most importantly a request that viewers call in with any information that might help solve cases.

There are a lot of scientific notions, mostly psychological, that explain the true crime genre's longevity and highly engaged fan base. One is pretty simple: closure. We love completing an unfinished puzzle. *Unsolved Mysteries* has reportedly helped close more than 260 files, and once led to arrests in less than a day.

Tapping into broad populations is something we talk a lot about at *Popular Science*. Research, data gathering, and study design all improve when the most diverse group possible gets involved. Endeavors also thrive when we can explore every reasonable rabbit hole, increasing the chances of illuminating something that has long lived in the shadows.

A relentless approach to unexplained phenomena is exactly what the perennial pop-culture hit and this mystery-filled issue have in common. It's why physicists are hunting for dark matter nearly a mile underground (page 38), why curators are X-raying Picassos (page 96), and why one photographer has crawled into some of the world's darkest caves (page 66). It's also why we expanded the mind-bendingness of Head Trip (page 102) and dedicated the Big Qs section (page 14) to unraveling the mysteries of diseases and how we can better fight them.

The method is universal. It's a process, a way of uncovering evidence, identifying potential answers, testing them, and starting again. Sound familiar? Perhaps a little like something you learned in fifth-grade science class? Well, riddle me that.

–CORINNE

FALL 2020

Editor-in-Chief Corinne Iozzio
Group Digital Director Amy Schellenbaum
Design Director Russ Smith

EDITORIAL
Features Editor Susan Murcko
Articles Editor Rachel Feltman
Senior Editor Purbita Saha
Technology Editor Stan Horaczek
DIY Editor John Kennedy
Senior Producer Tom McNamara
Engagement Editor Ryan Perry
Group Commerce Editor Billy Cadden
Associate Editors Sara Chodosh, Claire Maldarelli, Rob Verger
Assistant Editors Jessica Boddy, Sandra Gutierrez G.
Editorial Assistant Sara Kiley Watson
Copy Editor S.B. Kleinman
Researchers Kate Baggaley, Cadence Bambenek, Jake Bittle, Diane Kelly, Erika Villani, Grace Wade
Interns Hannah Seo, Candice Wang

ART AND PHOTOGRAPHY
Photo Director John Toolan
Art Director Katie Belloff
Consulting Production Manager Glenn Orzepowski

EDITORIAL PRODUCTION
Group Managing Editor Jean McKenna
Managing Editor Margaret Nussey

CONTRIBUTING EDITORS
Brooke Borel, Kat Eschner, Tom Foster, William Gurstelle, Gregory Mone, Sarah Scoles, P.W. Singer, Nick Stockton, James Vlahos, The Voorhes (photography)

Executive Vice President Gregory D. Gatto

BONNIER MEDIA
Senior Vice President, Managing Director John Graney
Digital Sales Manager Lee Verdecchia
Corporate Sales
Directors Kristine Bihm, Ann Blach, Kelly Hediger, Cynthia Lapporte, Matt Levy, Cyndi Ratcliff, Jeff Roberge
Direct Response and Classifieds
Sales Representatives Brian Luke, Chip Parham
Business Operations
Advertising Coordinator Nicky Nedd
Digital Content Production and Presentation
Director Michellina Jones
Producer Daniel McSwain
Bonnier Custom Insights
Director Michele Siegel
Research Analyst Ava Ziegler
Production
Group Director Rina V. Murray
Associate Director Kelly Kramer Weekley
Artist Pete Coffin
Consumer Marketing
Director Sally Murphy, ProCirc
Public Relations
Manager Cathy Hebert

BONNIER
Executive Chairman Dr. Jens Mueffelmann
Chief Executive Officer David Ritchie
Executive VP, Bonnier Media Gregory D. Gatto
Senior VP, Consumer Products Elise Contarsy
Senior VP, Events Jonathan Moore
Senior VP, Digital Operations David Butler
Senior VP, Managing Director, Corp. Sales John Graney
VP, Finance, Tax and Treasury Alex Gentry
VP, Finance, Business Operations Tara Bisciello
VP, Financial Reporting and Analysys Kamman Chow
VP, Enterprise Solutions Shawn Macey
Human Resources Director Kim Putman
General Counsel Jeremy Thompson

This product is from sustainably managed forests and controlled sources.

FOR CUSTOMER SERVICE AND SUBSCRIPTION QUESTIONS, such as renewals, address changes, email preferences, billing, and account status, go to popsci.com/cs. You can also call 800-289-9399 or 515-237-3697, or write to Popular Science, P.O. Box 6364, Harlan, IA 51593-1864. For reprints, email reprints@bonniercorp.com

Occasionally, we make portions of our subscriber list available to carefully screened companies that offer products and services we think might be of interest to you. If you do not want to receive these offers, please advise us at 515-237-3697.

STAN HORACZEK

CONTRIBUTORS

BY *SANDRA GUTIERREZ G.*

1. Riley Black

• Megalodon, a 50-foot shark known as the *T. rex* of the seas, almost certainly ceased to exist around 3 million years ago. But on page 46, writer and amateur paleontologist Riley Black poses the question: What if this toothy beast is still around? It's the kind of topic she's been considering since middle school, when she became obsessed with dinosaurs. In college Black poured that passion into a blog and eventually a career reporting magazine articles and books, the latest of which is *Skeleton Keys*. She now spends her summers wandering the desert, digging up fossils: "It's a way to time travel," she reflects.

2. Tomi Um

• It took four years for the career of Brooklyn-based illustrator Tomi Um to take off, but when it did, it was as big-time as it gets. Her drawings took over Grand Central Station and subway cars in New York City as part of a mattress ad campaign. "My mom finally understood what I did for a living!" she laughs. Sketching has always been her preferred practice; she went pro after graduating from Parsons School of Design. Deeply influenced by traditional Korean art and silkscreen printing, her illustrations (on pages 102 to 104 of this issue) generally feature crowded scenes, simple lines, and bright colors.

3. Rob Verger

• When *Popular Science* associate editor Rob Verger was earning an MFA in nonfiction writing at Columbia University, a funny thing happened: He ran out of material. His essays had centered on travel experiences in places like Nepal and Micronesia, but the well ran dry. "I realized that if I became a reporter, I'd have unlimited things to learn and write about," he says. Since diving into journalism, he's explored complex fields, from artificial intelligence to military aviation. On page 20, he investigates the tricky but essential question of how the United States should prepare for the next pandemic.

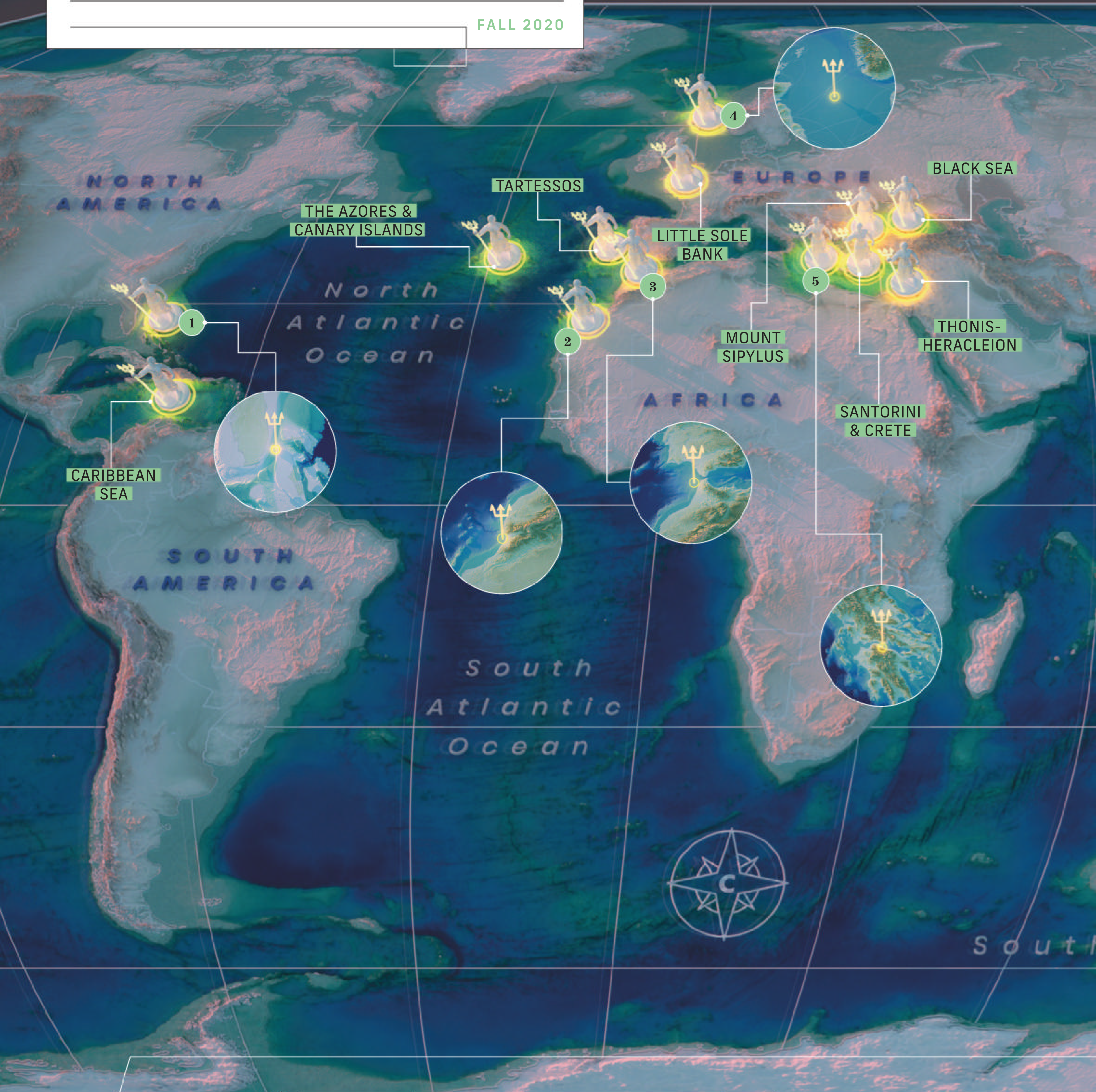
4. Robbie Shone

• Photographer Robbie Shone has visited more than 50 countries to explore their caves, a surprising tally for someone who never wanted to venture into one in the first place. In 1999, while working on his painting skills at the University of Sheffield, England, Shone agreed to accompany a friend underground. He knew bringing a canvas wouldn't be practical, so decided to take a camera instead. The trip sparked a lifelong pursuit. "There was such a rush of adrenaline," he recalls. His work on these hidden chambers has since been featured in many outlets, and now in this issue, beginning on page 66.

COURTESY CONTRIBUTORS; STAN HORACZEK (VERGER)

CHARTED

FALL 2020


NORTH AMERICA
THE AZORES & CANARY ISLANDS
TARTESSOS
EUROPE
BLACK SEA
LITTLE SOLE BANK
North Atlantic Ocean
1
2
3
4
5
MOUNT SIPYLUS
THONIS-HERACLEION
CARIBBEAN SEA
AFRICA
SANTORINI & CRETE
SOUTH AMERICA
South Atlantic Ocean
South

1/Bimini Road In the mid-’60s, divers encountered a remarkably straight half mile of evenly spaced, uniform stones. Carbon dating and a lack of tool marks suggest natural erosion is responsible, but some believe it’s from a sunken civilization.

2/Souss-Massa plain A 2008 analysis of 51 Platonic descriptors of Atlantis identified several possible coordinates, including these coastal dunes, which feature intriguing concentric dry riverbeds. Unfortunately, there’s scant evidence of any empire.

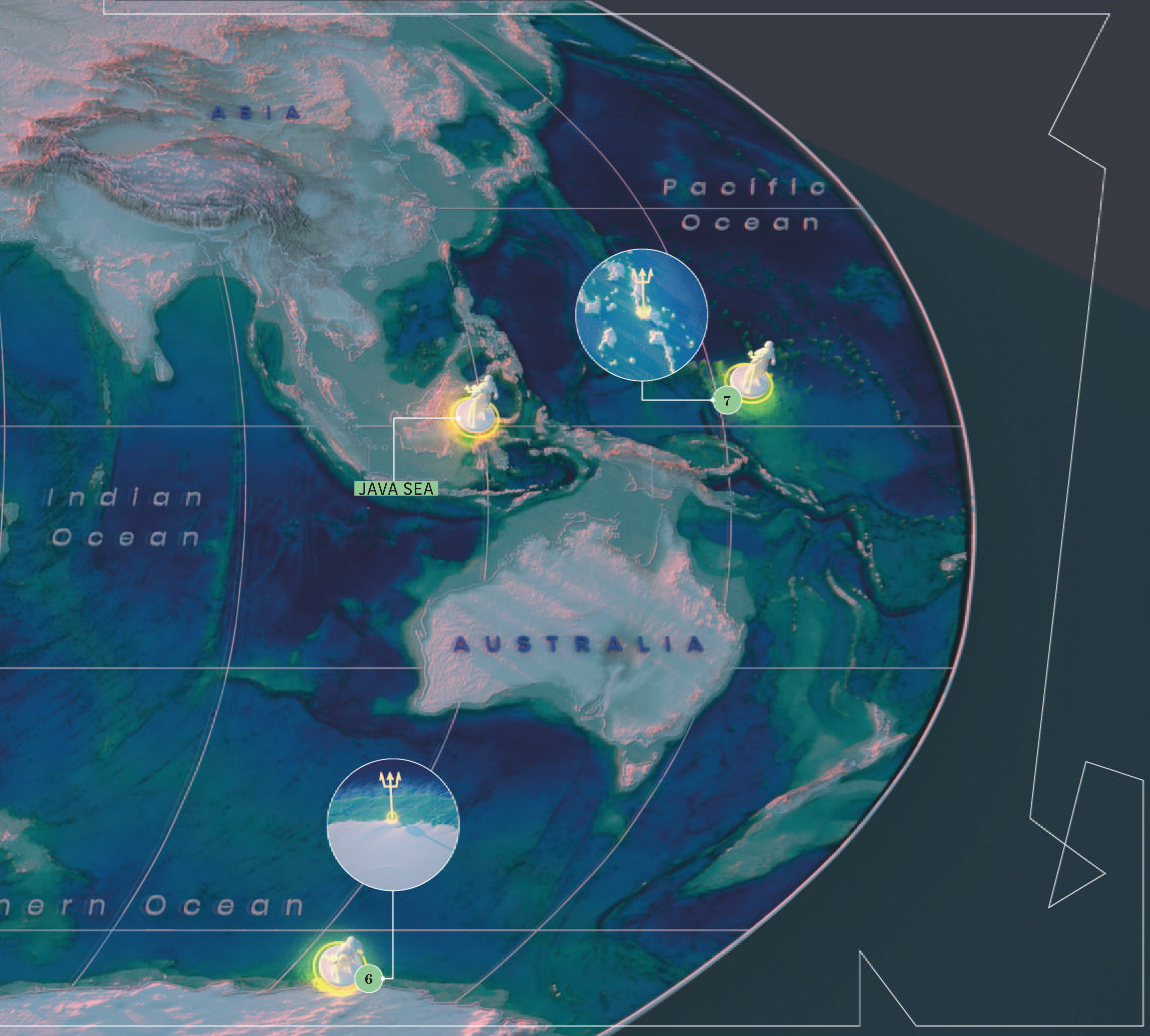
3/Spartel Bank Plato said the lost city lay beyond the Pillars of Hercules—two rocks in the Strait of Gibraltar. The island of Spartel once sat there. Passing sailors may have seen it vanish at the end of the last ice age, but if so, they left no records.

where we've 'found' atlantis

BY *ELEANOR CUMMINS* /
ILLUSTRATION BY *CRAIG TAYLOR*

PLATO FIRST DESCRIBED THE lost kingdom of Atlantis in 360 BCE. He wrote of a mountainous island crafted by Poseidon, filled with elephants and gold. But around 9,000 years prior, he claimed, earthquakes and floods sank the city into the sea.

He probably made the whole thing up. Still, that hasn't stopped Atlantologists from gathering "evidence" of its existence. Inspiration abounds: Coastal towns collapse and islands submerge, whether from rising oceans or sinking shorelines. These lost lands offer a setting for theories on where the city may once have stood.



4/Doggerland The British Isles were once connected to Europe by a low-lying landmass. But when a megatsunami struck around 6000 BCE, the region disappeared, leaving bones and tools from local hunter-gatherers embedded in the seafloor.

5/Helike A tsunami walloped this Greek town in Plato's day, and many assumed its remains lay in the Corinthian Gulf. But in the 1990s, archaeologists found it half a mile inland, buried under a few dozen feet of sediment by a process called soil liquefaction.

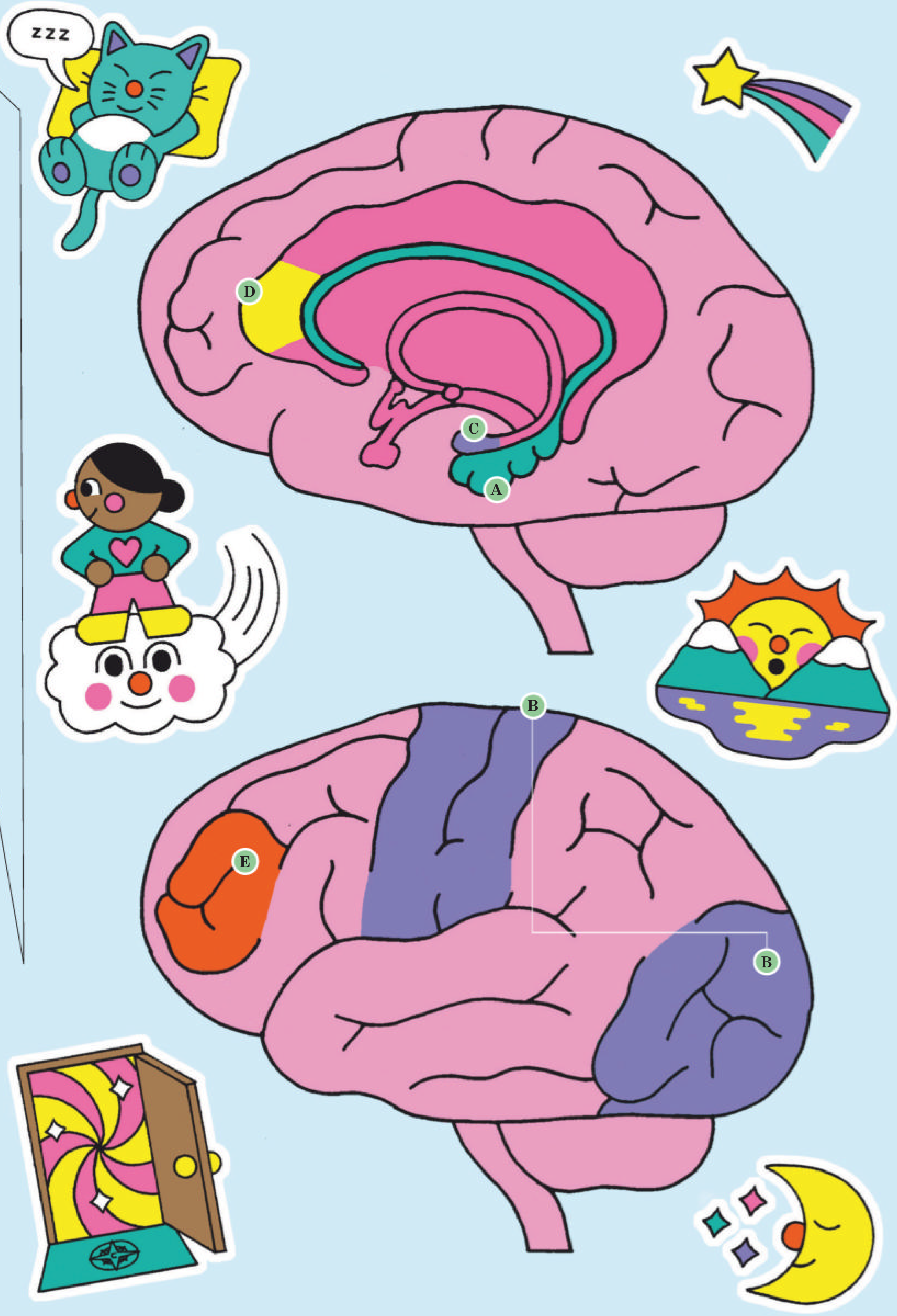
6/Antarctica Historian Charles Hapgood argued the southern continent was once a northern landmass with Atlantis on its shore. Then, 12,000 years ago, a shift in the crust sent it south. Antarctica did make that trip—some 30 million years ago.

7/Marshall Islands We may have another "Atlantis" someday. Sea level rise threatens coastal communities, including this network of atolls with an average elevation of just six feet. Without intervention, they'll likely be underwater by midcentury.

visions in the night

YOU DREAM FOR TWO HOURS every night, but for something so common, it's a remarkably enigmatic process. Only in the past few decades, with the advance of technology like fMRIs that lets us record and visualize activity in the brain, have neuroscientists begun to figure out how and why we experience these reveries. While sleepy interludes seem to rely on many of the same mental processes we use while awake, researchers are still trying to understand the way they work together during slumber. Here's how we think our brains drive our nocturnal hallucinations.

BY *LINDZI WESSEL*
ILLUSTRATION BY *STEPHANIE UNGER*



A/Remember

Dreams tap memories stored in connections between brain cells, which the hippocampus tracks as they form. At night it directs neurons to replay recollections, facilitating long-term storage. That could be why reality seeps into our visions—but not why they tend to warp reality.

B/Envision

Our most vivid imaginings occur during the REM phase of sleep. Activity increases in brain regions that control movement and process optical inputs, like the visual and motor cortices, which likely create what we "see" and "do" in slumber. It's not clear what triggers these areas at night.

C/Feel

The almond-shaped amygdala helps generate feelings like fear, anger, and anxiety. It and other emotional domains are more rowdy during REM sleep, which could explain why strong reactions happen frequently when we doze. We may rely on this process to dull the sting of difficult memories.

D/Decide

Despite their disjointed nature, dreams still contain semi-rational thoughts, likely thanks to areas supporting conscious cognition. The anterior, or front, portion of the cingulate, a semicircle in the brain's center, influences motivation and decision-making—and can switch on while we're snoozing.

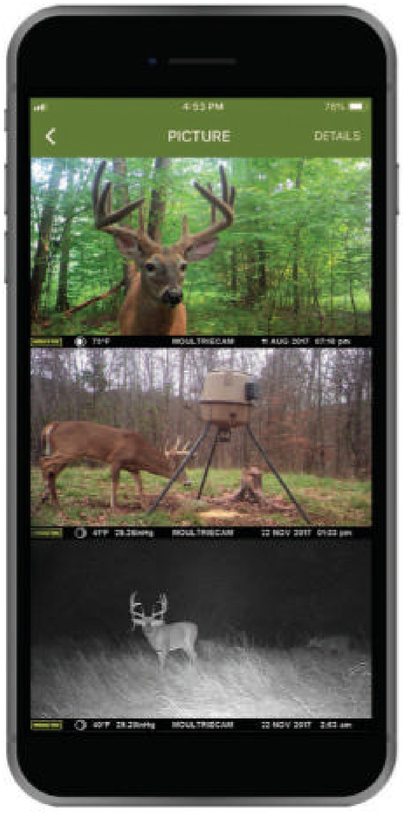
E/Escape

During REM, neuroscientists see suppression of the dorsolateral prefrontal cortex, which is critical for executive functions like directing attention, solving problems, and reasoning. This might help explain why we rarely realize we're asleep, despite some outlandish scenarios.

NEW INTERACTIVE MAPPING.

Save locations and drop pins for cameras, feeders, trails, bedding areas and more.

COMMAND CENTRAL FOR THE BEST DEER SEASON OF YOUR LIFE.



ALL-NEW 6000-SERIES CELLULAR TRAIL CAMERAS.

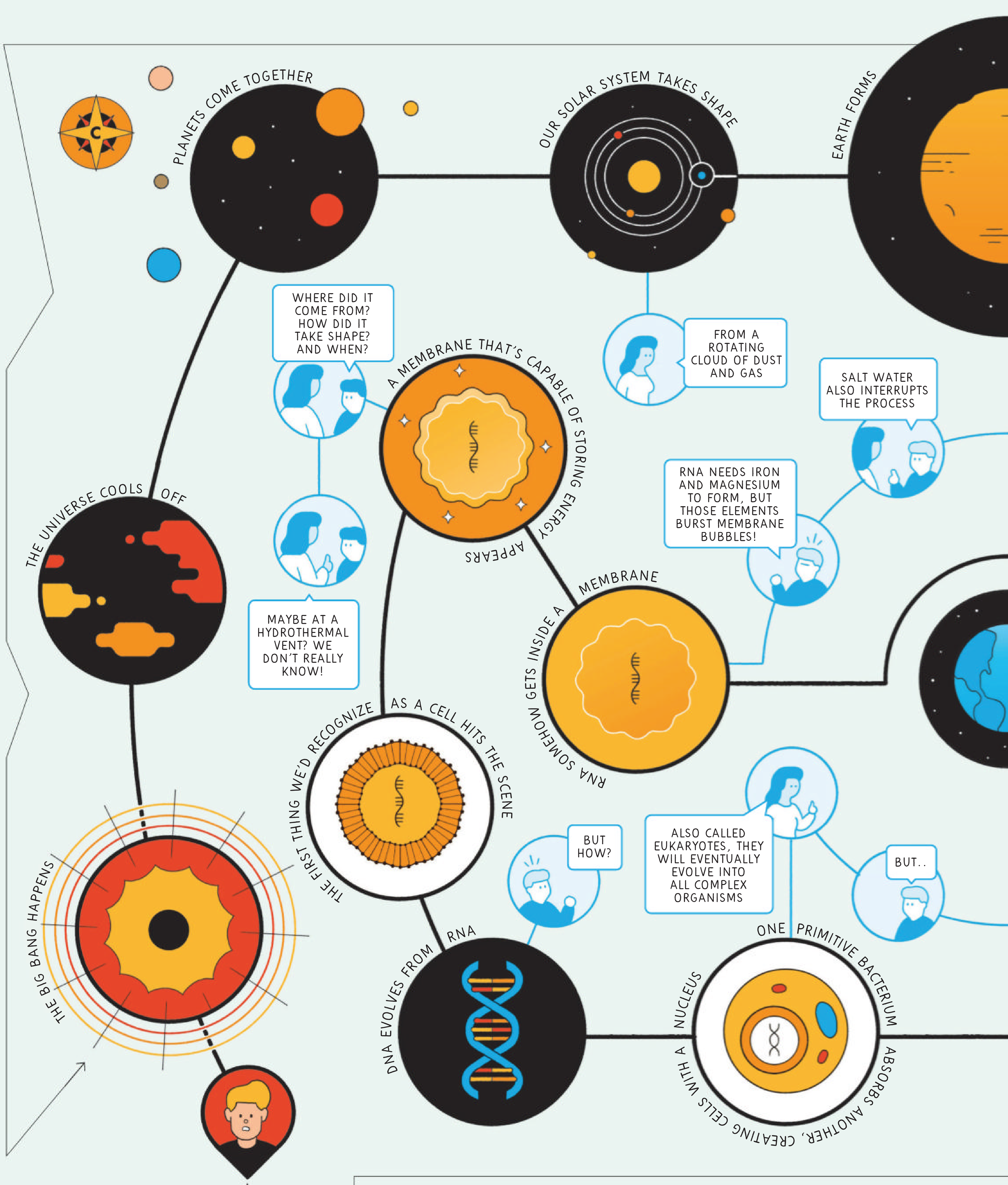
Rugged, reliable and powered by the industry's most advanced and easy-to-use software, Moultrie Mobile is the highest evolution of cellular trail cam technology. Simple setup & smart features, like interactive mapping and image recognition, help you build the ultimate hunting strategy. Receive instant notifications anytime, anywhere with cellular connectivity backed by your choice of the nation's top two providers.

MOULTRIE MOBILE™
SMART. SIMPLE. CELLULAR.

NEW XA 6000 – AT&T
NEW XV 6000 – VERIZON

Connected by AT&T
connected by verizon✓

Shop now at moultriemobile.com


THE BIG BANG HAPPENS
THE UNIVERSE COOLS OFF
PLANETS COME TOGETHER
OUR SOLAR SYSTEM TAKES SHAPE
FROM A ROTATING CLOUD OF DUST AND GAS
EARTH FORMS
A MEMBRANE THAT'S CAPABLE OF STORING ENERGY APPEARS
WHERE DID IT COME FROM? HOW DID IT TAKE SHAPE? AND WHEN?
MAYBE AT A HYDROTHERMAL VENT? WE DON'T REALLY KNOW!
RNA SOMEHOW GETS INSIDE A MEMBRANE
RNA NEEDS IRON AND MAGNESIUM TO FORM, BUT THOSE ELEMENTS BURST MEMBRANE BUBBLES!
SALT WATER ALSO INTERRUPTS THE PROCESS
THE FIRST THING WE'D RECOGNIZE AS A CELL HITS THE SCENE
DNA EVOLVES FROM RNA
BUT HOW?
ONE PRIMITIVE BACTERIUM ABSORBS ANOTHER, CREATING CELLS WITH A NUCLEUS
ALSO CALLED EUKARYOTES, THEY WILL EVENTUALLY EVOLVE INTO ALL COMPLEX ORGANISMS
BUT..

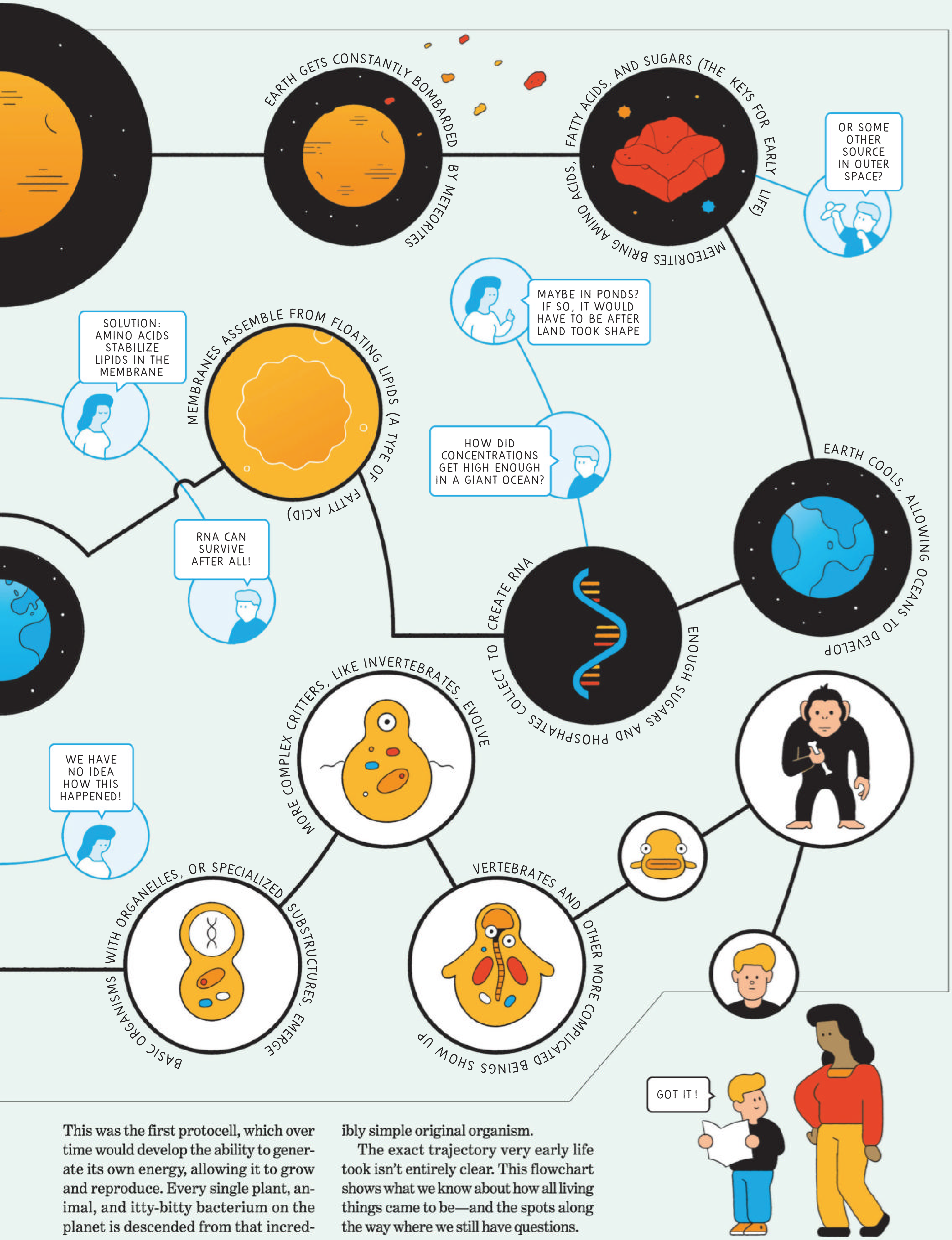
FLOWED

how life began

BY *SANDRA GUTIERREZ G.* /
ILLUSTRATION BY *GIACOMO GAMBINERI*

WE KNOW LIFE GOT ITS START around 4 billion years ago, when a drop in the Earth's temperature produced conditions that allowed the first organisms to thrive. Beyond that, the details of our origin story are still fuzzy.

Most researchers agree that the key to the emergence of living things lies in DNA's single-stranded cousin, RNA. At some point this molecule, along with a handful of proteins, found itself surrounded by a membrane of fatty acids.


EARTH GETS CONSTANTLY BOMBARDED BY METEORITES
METEORITES BRING AMINO ACIDS, FATTY ACIDS, AND SUGARS (THE KEYS FOR EARLY LIFE)
OR SOME OTHER SOURCE IN OUTER SPACE?
EARTH COOLS, ALLOWING OCEANS TO DEVELOP
ENOUGH SUGARS AND PHOSPHATES COLLECT TO CREATE RNA
HOW DID CONCENTRATIONS GET HIGH ENOUGH IN A GIANT OCEAN?
MAYBE IN PONDS? IF SO, IT WOULD HAVE TO BE AFTER LAND TOOK SHAPE
MEMBRANES ASSEMBLE FROM FLOATING LIPIDS (A TYPE OF FATTY ACID)
SOLUTION: AMINO ACIDS STABILIZE LIPIDS IN THE MEMBRANE
RNA CAN SURVIVE AFTER ALL!
WE HAVE NO IDEA HOW THIS HAPPENED!
BASIC ORGANISMS WITH ORGANELLES, OR SPECIALIZED SUBSTRUCTURES, EMERGE
MORE COMPLEX CRITTERS, LIKE INVERTEBRATES, EVOLVE
VERTEBRATES AND OTHER MORE COMPLICATED BEINGS SHOW UP
GOT IT!

This was the first protocell, which over time would develop the ability to generate its own energy, allowing it to grow and reproduce. Every single plant, animal, and itty-bitty bacterium on the planet is descended from that incredibly simple original organism.

The exact trajectory very early life took isn't entirely clear. This flowchart shows what we know about how all living things came to be—and the spots along the way where we still have questions.

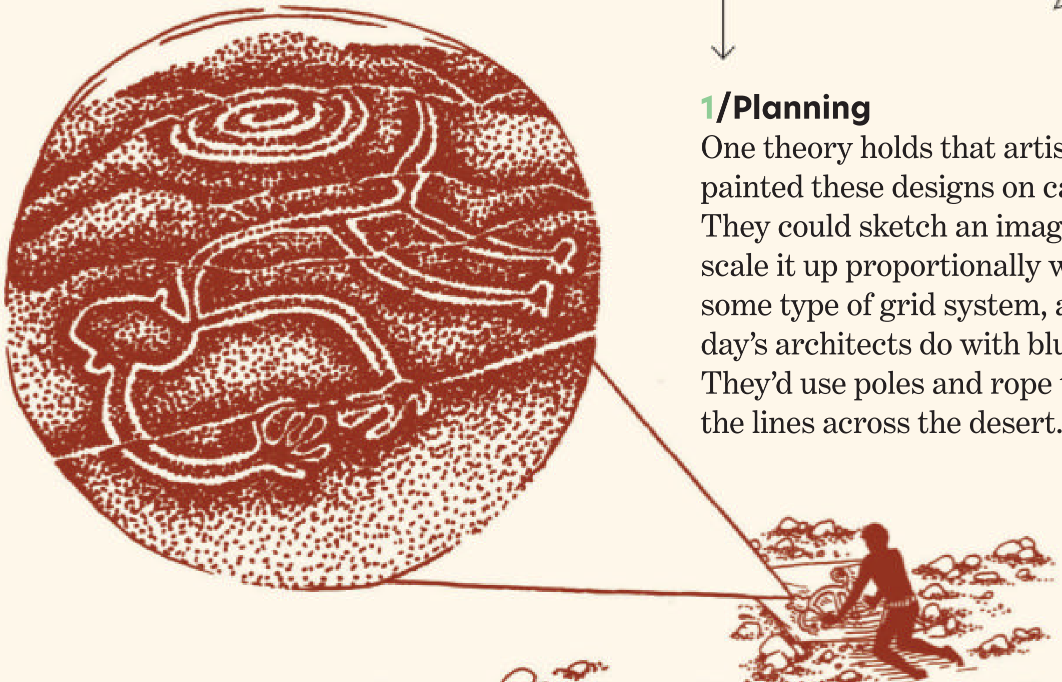
alien art?

BY *SARA KILEY WATSON*
ILLUSTRATION BY *LUCY ENGLEMAN*

IF YOU FLY OVER THE DESERT on the southern coast of Peru, you'll spot dozens of line drawings, stretching hundreds of feet across the arid landscape. The Nazca people created these images—depicting such characters as a whale, a hummingbird, and an astronaut-esque man—nearly 2,000 years ago. The etchings may have served as a massive astronomical calendar or offered tribute to the gods, though their actual purpose still eludes historians. While some suspect alien interference, the methods the Nazca used probably aren't quite so far-fetched.

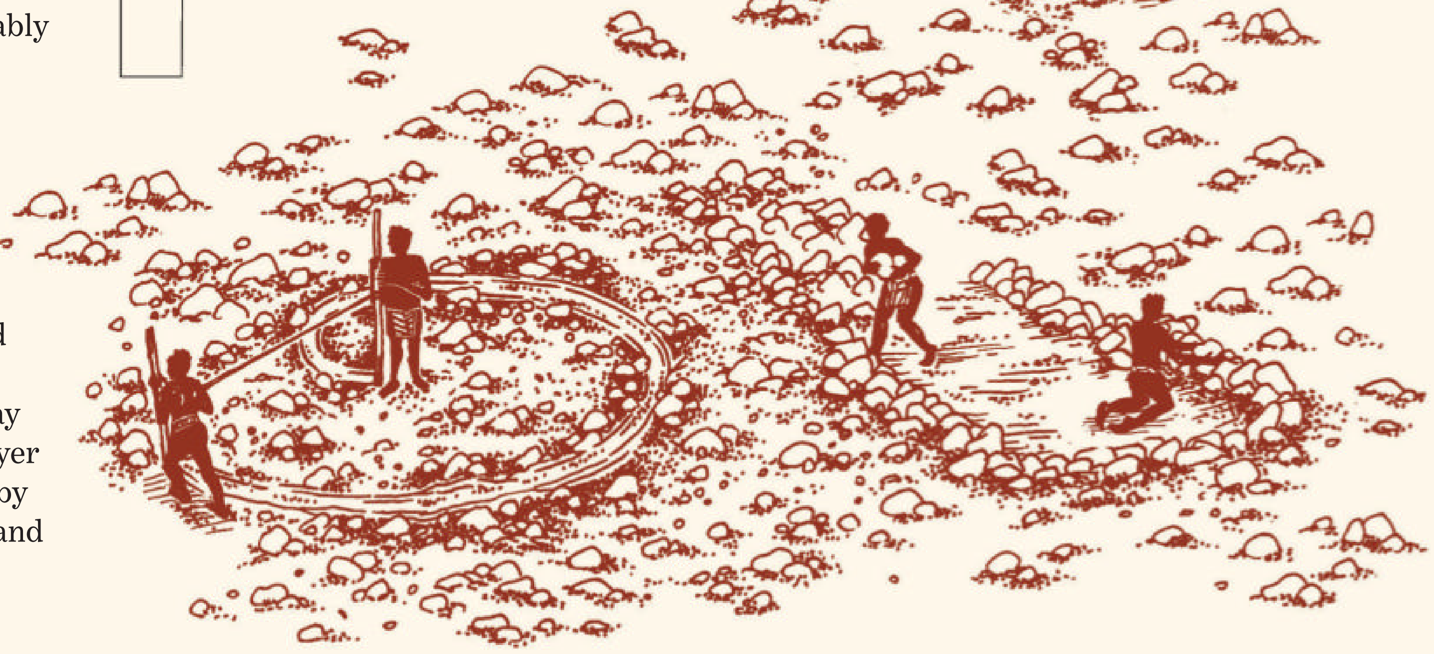
1/Planning

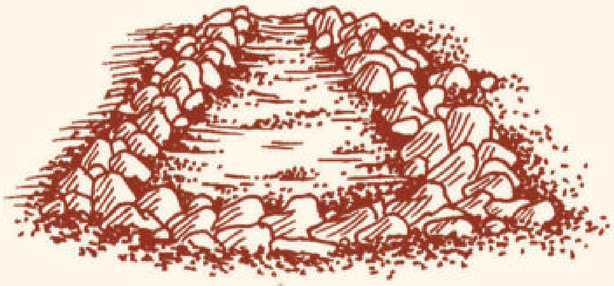
One theory holds that artists first painted these designs on canvas. They could sketch an image, then scale it up proportionally with some type of grid system, as today's architects do with blueprints. They'd use poles and rope to map the lines across the desert.

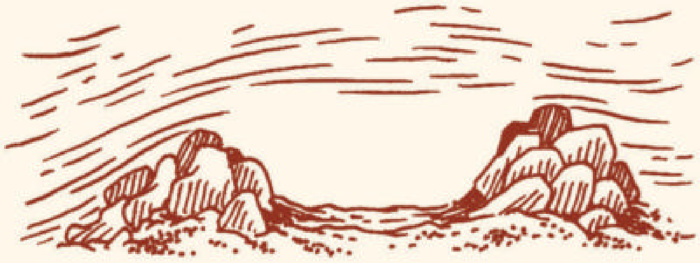


2/Creation

To create straight lines, the Nazca people would pull a cord taut between two stakes, then etch the paths by scraping away dark rock to reveal a lighter layer beneath. They created spirals by tying a cable to a central post and walking around in circles.

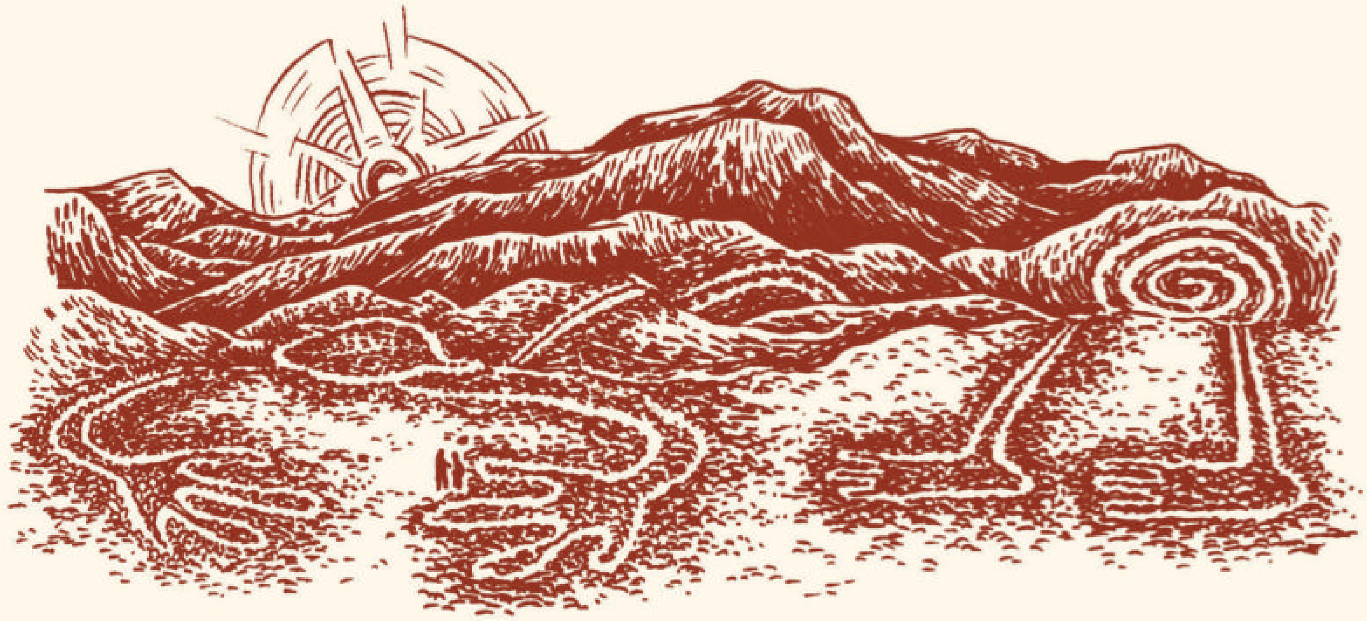






3/Preservation

Winds and rain could easily turn the desert back into a blank russet canvas. That's why the Nazca piled up oxidized stones on the sides of their markings; the rocks are heavy enough to withstand gusts and the region's scant rain, protecting the lines within.



4/Viewing

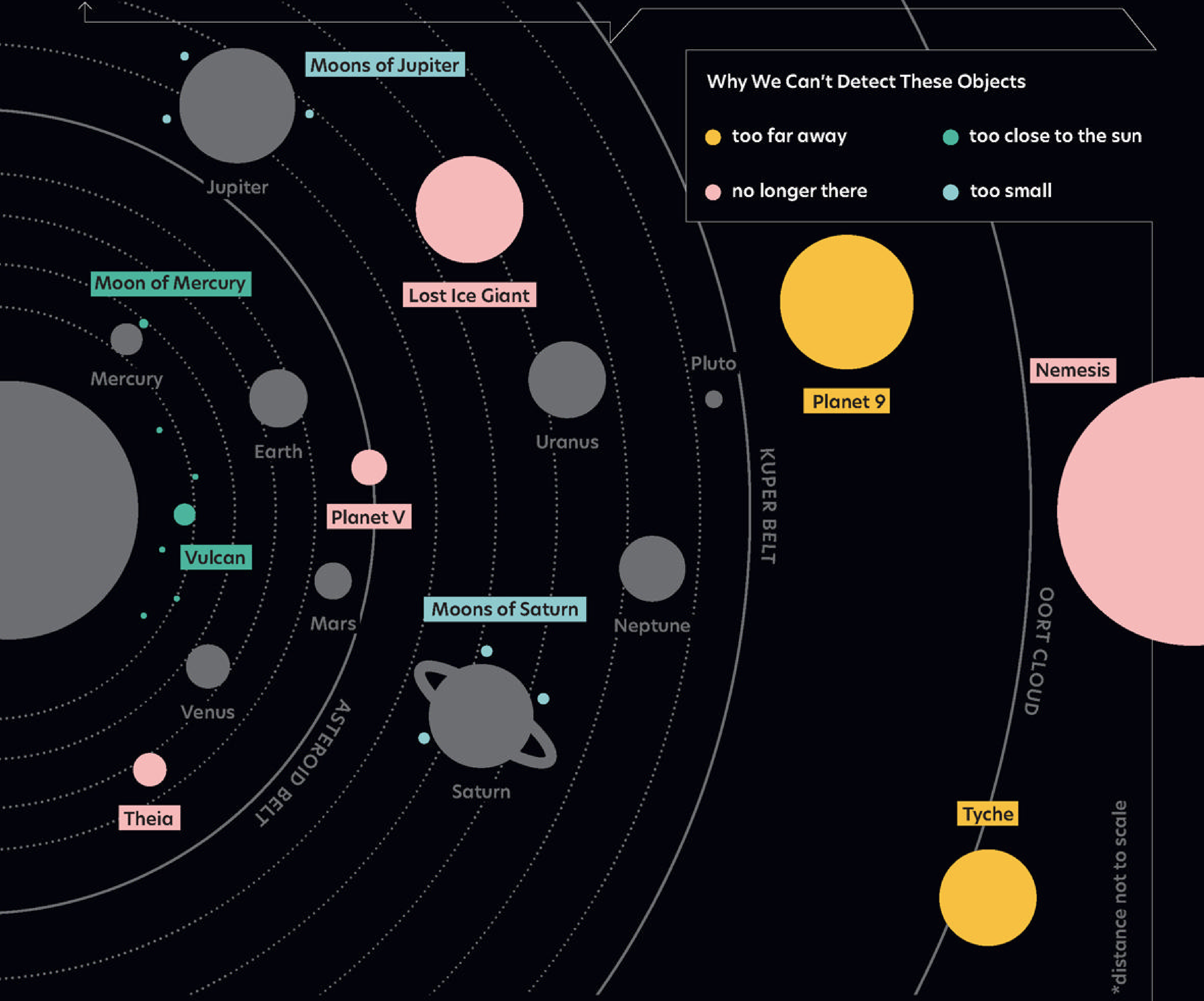
These sketches caught public attention in the early 20th century, as planes gave us a bird's-eye view—the best way to take them in. But the Nazca didn't need anachronistic (or alien) flying machines to see their creations: They're visible from nearby mountain peaks.

Vulcan and the Vulcanoids
Astronomers once interpreted an oddity in Mercury's orbit as a sign of a planet hiding in the sun's rays. Einstein's theory of gravity explained it away, but the zone could harbor asteroids ("vulcanoids"). They'd be small: NASA's twin sun-observing STEREO spacecrafts would have spotted any wider than a few miles.

Lost Ice Giant
In digital reenactments of its early days, the solar system gets rowdy. Near collisions between planets end with Jupiter sending Uranus or Neptune flying in 99 simulations out of 100. Yet both remain. One explanation: A third body took the hit. Calculations hint that a massive, icy planet could have tussled with Jupiter and lost.

Planet 9
Hundreds of specks appear clustered beyond Neptune, a hint that something up to 10 times as massive as Earth might lie beyond. A large planet could supply the necessary gravitational influence to pull them in. New evidence for this celestial body—possibly a rogue world from interstellar space—was unveiled in 2016.

Nemesis
Semiregular extinctions on Earth suggest a dim companion star might have periodically careened by, showering us with meteorites dragged in its wake. But any such sibling is gone. A 2010 sky survey found thousands of new stars, some just six light-years away. Nemesis, which would lie at one-quarter that distance, was absent.


Moons of Jupiter
Jupiter
Lost Ice Giant
Moon of Mercury
Mercury
Earth
Pluto
Planet 9
Nemesis
Uranus
Planet V
Vulcan
KUPER BELT
Mars
Moons of Saturn
Neptune
OORT CLOUD
Venus
ASTEROID BELT
Saturn
Theia
Tyche
*distance not to scale

Why We Can't Detect These Objects

- ● too far away
- ● too close to the sun
- ● no longer there
- ● too small

ABSTRACTED

the unknown parts of our solar system

BY *CHARLIE WOOD* / ILLUSTRATION BY *SARA CHODOSH*

ASTRONOMERS HAVE SPENT centuries filling in their sketches of our corner of the Milky Way. But these charts, like all maps, are only approximations of reality. Their blind spots likely harbor some unknown entities—bodies too small, too close to the sun, or too far away for us to see. Here are some celestial objects that stargazers have suspected of dodging their telescopes over the years.

VACCINE HACKING • VANQUISHED PATHOGENS • VIROLOGY SLEUTHS • VIGOROUS HAND-WASHING

BIG QS

SPECIAL EDITION

The Mysteries of Disease

POV

HOW DO WE TRACK A CONTAGION WE KNOW NOTHING ABOUT?

BY *ELEANOR CUMMINS* / PHOTOGRAPH BY *AMANDA RINGSTAD*

IN 1995, ERIC PEVZNER TOOK A TEMPORARY GIG AT HIS alma mater, Michigan State University, while he applied to med school. But this project—investigating how a sense of community influences wellness—intrigued him in a way a clinic never could.

Within the heaps of paperwork, he uncovered a compelling combination of science and service. "I didn't really understand anything about the field," Pevzner says of his first foray into public health. By uniting disparate fields like psychology and economics, he and his colleagues were finding ways to improve people's lives.

Pevzner never did end up in med school. Instead the research led to a fellowship at the U.S. Centers for Disease Control and Prevention (CDC), which in 2005 ushered him into a more mysterious side of medicine: compositing scattered patient stories into detailed portraits of disease. He's spent his career as a scientific sleuth, and now serves as chief of the CDC's Epidemic Intelligence Service (EIS), an elite postgrad program producing the world's best health detectives.

Founded in 1951 to address the threat of biological tactics in the Korean War, the EIS has trained more than 3,800 officers, Pevzner included. Epidemiologists, doctors, nurses, and even veterinarians learn to chart the chain of transmission through people who have been exposed to a pathogen and those they may have in turn infected. Officers tap patients' memories, documents like payroll logs and flight manifests, and technologies like cellular location data and computer modeling. With each new link, EIS experts refine their answers to the big questions: how contagious a disease is, who's at risk, and what policies might help to curb its spread—from social distancing to funding vaccine development.

EIS officers and alumni have tackled every major modern public health crisis, including vaping, HIV, and opioid addiction. Pevzner, who took over the program in 2017, still heads into the field—though day to day he focuses more on developing coursework and swapping insights with similar programs around the world. In 2006, for example, he investigated an unusual tuberculosis outbreak among methamphetamine users in Washington state. By poking through health records, his team determined the cases were all linked to an earlier outbreak in the 1990s through an infected woman who didn't complete her antibiotic regimen. The investigation also revealed a larger pattern: A lack of transportation and housing kept many people from finishing treatment. Pevzner suggested providing patients with temporary shelter and financial support, measures that helped public health officials stem the bacteria's spread.

In 2020, COVID-19 has presented EIS with one of its trickiest fact-finding missions, and a new priority for Pevzner and his colleagues. With little warning and no prior knowledge of the disease, which emerged in China's central Hubei province in late 2019, the EIS has had to develop expertise on the pandemic in real time.

Pevzner, along with seven past and present officers, began tracing COVID-19 on the ground this past March, after an EIS alum working in Salt Lake County, Utah, invited them to visit. They went from household to household, gathering data via surveys, swabs, and blood samples to calculate the virus's "attack rate"—the percentage of an exposed population that contracts the disease in a given period. Tallying this within families can help estimate community spread and guide healthcare systems as they stock supplies and ramp up service. To evade nosy neighbors, the team donned their personal protective equipment stealthily in backyards and garages. "Many people have never seen someone in full PPE, except in movies like *Contagion* or *Outbreak*," Pevzner says of the anxiety-provoking combination of gowns, face shields, gloves, and masks.

As new clues surface, the team's practices change too. For instance, when reports emerged citing loss of smell and taste as symptoms of COVID-19, Pevzner's crew modified its surveys and circled back to previous interviewees. Without this tidbit, the investigators might have overlooked some patients, allowing the infected to unknowingly continue transmitting the disease.

The constant doubling back can be frustrating, Pevzner admits, but the detectives train to keep up. Whether it's the present pandemic or the next novel disease, the best way to track and stop a pathogen is to adapt alongside it. "We have to be nimble," he says.

Gallery View
Exit Full Screen
Talking: Eric Pevzner
End
Mute
Stop Video
Security
Participants
Chat
Share Screen
Record
Reactions

MICHELE ANDREWS (PROP STYLING)

LITTLE Q

IS HAND-WASHING REALLY A PANACEA?

BY *KAT ESCHNER*

SOAP, WATER, AND TIME: That's the recipe for healthy paws. For thousands of years, entire religions and cultures have leaned on the practice for cleanliness, but it's become more popular in the past two centuries as the sanitizing power of sudsing agents and running H_2O have become more clear. Still, is the simple act as effective at thwarting microbes as we think?

"Hand-washing is a catch-all preventive measure," explains Emory University epidemiologist Matthew Freeman; it rids our skin of foodborne germs, chemicals, and other undesirable substances. The suds, for the most part, don't kill pathogens. Soap is a surfactant, which means it makes it easier to clear away oils and dirt. Water then rinses off the contaminants, carrying along microbes for the ride. "By rubbing your hands together, you create the friction to get them off," Freeman says. Health experts recommend doing this for 20 to 30 seconds for maximum effectiveness.

Such rigor can clean off anything from *E. coli* to the novel coronavirus. A study in the *American Journal of Public Health* suggests that regular hand-washing cuts cases of gastrointestinal illnesses by 30 percent and of respiratory infections by 20 percent.

Still, the safeguard isn't a universal solution. Nearly half the world's population doesn't have access to a sink and a bottle of Dial. There's also the question of whether what we do after we wash our hands helps or harms the pathogen-stripping process. So far medical researchers know that wet skin can pick up loads more bacteria, possibly rendering the whole sanitizing process useless. Wiping fingers and palms with a paper towel might prove better than running them under a jet air dryer, but that step of this seemingly simple formula needs to be tested and probed by many more folks.

WHERE WE WENT WRONG

WILL DISEASES ALWAYS OUTSMART US?

When you've been publishing for a century and a half, some off-base ideas are going to creep into your pages. We're diving into the archives to give you a fresher take on "popular science."

BY *PURBITA SAHA*

IN 2008, KORONIS PHARMAceuticals wrapped up the second phase of trials for a new HIV treatment described as a "mutation booster." *PopSci* soon wrote about the intriguing procedure, which would supposedly introduce mistakes into the virus's DNA and cause it to self-destruct: "In the movies, this technique, known as lethal mutagenesis, would create a supergerm, but in real life it's spawning a powerful new class of antiviral drugs."

The therapy failed to trigger viral suicide, and experiments ceased. HIV deaths have since fallen sharply thanks to prophylactic medication, safe sex, and drugs that keep the pathogen from replicating, but the virus continues to elude one-shot methods. "It plays a cat-and-mouse game with the immune system," says Bali Pulendran, a professor of immunology at Stanford. HIV mutates at breakneck speed, throwing off any specialized response human cells create to fight it.

Regardless, Pulendran thinks our bodies may hold the key. In 2020 he and his colleagues used careful doses of HIV to trigger a flood of antibodies in a monkey's reproductive tract. Most subjects were protected for six months. And back in 2019, another group effectively cured a patient by giving him stem cells endowed with a rare, beneficial gene mutation.

All these tiny breaks in the case could add up in time. "I wouldn't be surprised if in a decade we have a vaccine with 50 percent protection," Pulendran says. (That's on par with the flu shot.) Paired with existing stopgaps, that could be what it takes to outmaneuver the powerful germ—no sci-fi cure-alls required.

EXPLAIN THE IMMUNE SYSTEM LIKE I'M 5

BY *SARA KILEY WATSON*

THE IMMUNE SYSTEM, WHICH IS MADE UP OF white blood cells, the spleen, and bone marrow, acts like an invisible cavalry in our bodies. When it spots an intruder like a virus, it dispatches Y-shaped antibody proteins that lock on to a particular baddie to mark it for attack. But the strategy isn't exactly perfect.

Sometimes the microscopic defense revolts, and doctors are still baffled as to why. What they do know, though, is that when things go haywire, our internal fighters can destroy healthy cells and organs, causing lupus and other illnesses in at least 20 million Americans. Daniel Davis, a professor of immunology at the University of Manchester, says it's possible that antibodies end up targeting the wrong bits because certain dastardly germs can resemble human proteins.

In other cases invaders might overwhelm the first line of attacking white blood cells, triggering a harmful overreaction. As long as our immune systems are constantly doing battle, they're liable to mistake some friends for foes in the trenches.

HOW DO ANIMALS FIT INTO THE VIRAL PUZZLE?

AS TOLD TO *SANDRA GUTIERREZ G.*

THE COVID-19 ORIGIN STORY IS MURKY AT BEST. Epidemiologists agree that the disease likely thrived in bats before it made the zoonotic leap to humans—plus pangolins, dogs, cats, tigers, lions, and minks. But that's about where the consensus ends.

Biologists and virologists need to dissect how different creatures interact with germs like SARS-CoV-2, which causes COVID, to understand how public health crises emerge. Part of that means digging into human-wildlife relationships—and how they change as people take over more of the world. We asked the experts where threats lurk as we push those barriers, and what more we need to learn.

People are concerned about weird contact in species in the wildlife trade—but the biggest risks are climate change and land use. Both displace animals and cause possible reservoirs of disease. I don't think there's anything we could do to disturb viruses that compares to the massive problem we've created by shaking the world like a snow globe.

—Colin Carlson,
assistant research professor
at the Center for Global
Health Science and Security
at Georgetown University

There are likely undiscovered viruses that exist in nature that threaten humanity, directly or indirectly. Some might cause deadly illnesses in certain species and individuals, depending on dose, age, innate resistance of the host, and many other factors. But generally, fatalities are unusual, because pathogens need a healthy animal—whether it be a butterfly, elephant, or barnacle—in order to survive.

—Charles Calisher,
professor emeritus at
Colorado State University's
department of microbiology,
immunology, and pathology

Our level of contact with wildlife varies a lot, especially as we encroach on habitats. Virus transmission can occur when we share the same space or through direct contact like hunting and food processing. With domestic animals, just cleaning up their waste and getting licked can expose a person to zoonotic pathogens.

—Kishana Taylor,
virologist at the
University of
California, Davis

As more fish are raised in captivity, we discover new microbes in them like rhabdovirus, which causes bleeding, anemia, and rapid death through a condition called viral hemorrhagic septicemia. We still don't know the mechanisms that allow pathogens to inflict harm on the food we eat, even as we're working on developing better vaccines to combat such viruses in aquaculture. There's been some progress, but breakthroughs come slowly.

—Rodman Getchell,
assistant research
professor at Cornell
University's College of
Veterinary Medicine

POSTCARD

WHY DOES PATIENT ZERO MATTER?

BY *JACK HERRERA*

IN EARLY DECEMBER OF 2013, Emile Ouamouno, a 2-year-old boy in southern Guinea, began vomiting from an unknown illness. A few days later, he died. Then, just around New Year's, his mother and sister succumbed to similar symptoms.

This is the story that their father, Etienne Ouamouno, told disease specialists when they arrived in his village in hazmat suits the following year. Using viral samples collected from dozens of Guineans, a European lab confirmed the cause: Ebola, a highly infectious pathogen picked up from bats that kills close to half of its victims, often via hemorrhaging. But the tests didn't identify the origins of the outbreak—so doctors headed back into the field to interview those affected about their comings and goings.

After three months of fact-finding, the chain of cases led back to Etienne, whose son epidemiologists now consider patient zero for the 2014 Ebola epidemic. The two-year rampage spurred the creation of a vaccine that was approved by the United States in 2019.

Tracking down a virus's first human host serves a critical function. In smaller outbreaks it helps public health officials isolate sick people and stop the spread of a disease. In large ones it lets scientists mark the start of the epidemic curve and chart how a contagion moves through a population.

Most of the work requires "shoe-leather epidemiology," says Ron Waldman, a global-health professor at George Washington University. "You couldn't do it all in a lab," he explains.

While there's no replacement for door-to-door detective work, genetic analysis tools now offer a shortcut to the roots of a disease. During the COVID-19 pandemic, for instance, it took researchers just over a month to follow multiple strains of viral DNA to entry points around the United States.

Documenting COVID won't reverse any harm, but "it allows us to learn how the virus got into the population," Waldman says. "That would have tremendous implications for controlling these kinds of events in the future."

FORECAST

CAN WE COOK UP VACCINES ANY QUICKER?

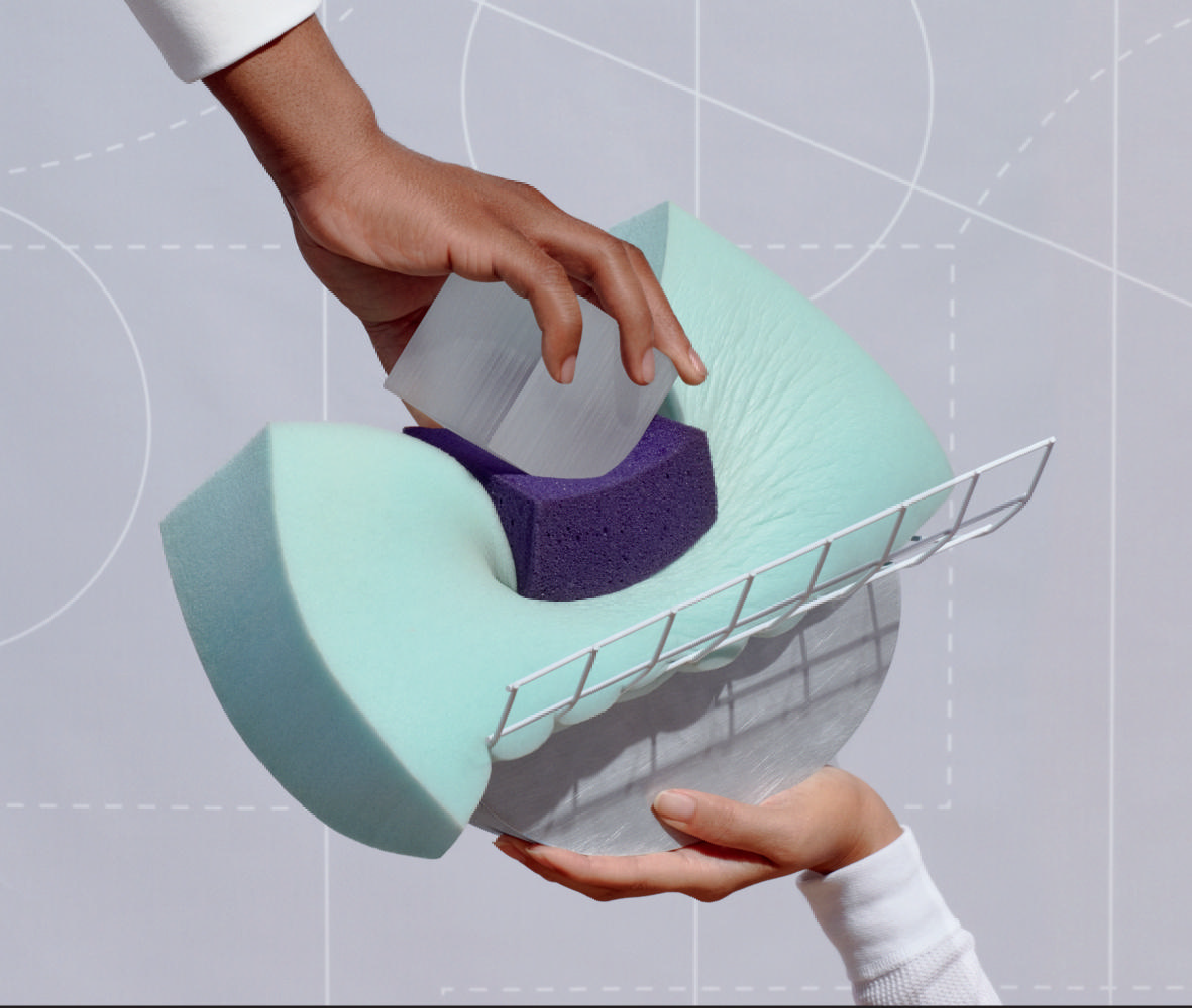
BY *ULA CHROBAK*

BEFORE VACCINES, physicians would blow smallpox scabs up people's noses or stab them with pus-laced needles to build up their resistance to the virus. It usually worked: Patients would feel mildly ill, then grow immune. But because the pathogen was still living inside them, they could spread it to others.

By the 1930s, medical researchers had figured out how to breed harmless forms of bugs to stuff into sterilized injections. Since then, vaccines have saved tens of millions of lives, but the pace of development can be glacial. Over the past century, it's taken an average of 25 years to create a "dead" virus that can protect humans. But when faced with new and rapidly spreading contagions, could a different approach cut that timeline down to just a few months?

One experimental method involves dosing patients with small bits of viral DNA and RNA instead of a genetically watered-down version of the pathogen itself. By shooting synthesized pieces of a virus's genetic code straight into the body's defense systems, we might teach white blood cells to recognize and ambush diseases like influenza, explains Shane Crotty, a professor at La Jolla Institute for Immunology. The workaround could allow new vaccines for Zika, rabies, and more unfamiliar illnesses to reach large-scale clinical trials in less than a year.

The real game changer, though, will come when virologists no longer need to design vaccines that combat specific strains. For infectious pathogens that mutate quickly, immunologists like Crotty might scout out the proteins in a germ's genetic makeup that don't change and craft synthetic versions, allowing the body to track intruders even after they've morphed. Such treatments may become available in the next decade. With a portion of the code already deciphered, drug companies would have what they need to vaccinate people safely and at record speed.



Too many people are getting injured playing hockey, and it's putting the game's future at risk.

We wanted to change that.

Together with the Pittsburgh Penguins and high-tech polymer company Covestro, we are inventing safety innovations without impacting game play.

It's time to make hockey safer for professional and junior players alike.

Visit our site to learn more about how future rink dasher boards, player equipment and helmets are being engineered for safety.

The most complex problems.
The most diverse experts.

College of Engineering

ADVANCED COLLABORATION®

Carnegie
Mellon
University

Visit Rethink the Rink: ENGINEERING.CMU.EDU/RINK

THE BIG Q

How Do We Prep for the Next Pandemic?

BY ROB VERGER

TYPOGRAPHY BY
RUS KHASANOV

COVID-19 IS POISED TO enter the history books as a catastrophic pandemic. While combating a new disease is difficult, we can't blame this outbreak's losses on the pathogen's novelty alone. We also suffered from a lack of preparedness.

As early as February 2020, there were signs that the virus, which had emerged in Wuhan, China, in late 2019, would spread globally, notes Jeremy Konyndyk, an expert in outbreak readiness and a senior policy fellow at the Center for Global Development think tank. Most nations didn't implement preventive measures until March or April. "A big distinguishing feature of countries that have done well—or even, in the US, areas that have done well—is timing," he says. The other half of the equation, Konyndyk points out, is how well governments reacted once the pandemic hit.

We know COVID-19 won't be our last global outbreak. Experts point toward a spate of recent public health crises—SARS in 2003, the H1N1 scare of 2009, and Ebola in 2014—as indications that the interconnected, fast-moving nature of the modern world makes the spread of new illnesses unavoidable. But how can we get ready for an unknown pathogen?

The first step is to identify potential threats so we know where to focus preventive measures. The good news is that virologists already do this by taking samples from wild animals—birds, swine, bats—that harbor microbes capable of jumping to humans the way SARS-CoV-2, the baddie that causes COVID-19, did. But public health scholars say we should also do a lot more to keep up *after* a new bug makes the leap. Specifically, they recommend a national modeling center that shows how a pathogen might spread and ensures we have the information we need to make tough decisions about it. This federal-level hub could monitor viral trends and track the readiness of supply chains for therapies and protective equipment.

Experts like Konyndyk take inspiration for this would-be institution from our handling of another disastrous phenomenon: cyclones. They point to the National Hurricane Center, a part of the National Weather Service that projects when and where a storm might hit, complete with a cone of uncertainty—the known unknowns of a forecast. An office like that for infectious disease modeling, Konyndyk says, could distribute information to public officials and the masses. The Centers for Disease Control and Prevention (CDC) and other government agencies do some of this already, but it's "piecemeal," he says: "Are they definitive, systematic, intentionally communicated, intentionally public facing, in the way that the National Hurricane Center is? Not at all."

Such a hub could bring virologists, epidemiologists, and biostatisticians together under one roof in an organization that might sit toward the upper levels of the Department of Health and Human Services. If nothing else, this would help ensure we would have enough nimble and well-funded minds dedicated to tracking contagions at any given time—something that's not currently a given. Caitlin Rivers, an epidemiologist at the Center for Health Security at Johns Hopkins University, estimates that the government typically employs just a handful of infectious disease modelers, who quickly become swamped in a crisis. "What usually happens is academics drop what they're doing and volunteer to do this work," she says, which isn't how other crucial public systems operate. "When there is a hurricane off the coast of Florida, we're not like, 'Who wants to model?'"

Transmission modeling can guide policymakers in safeguarding the populace. The process involves gathering data and devising formulas to study how a bug will affect us under varied conditions. For example, if SARS-CoV-2 spreads more in crowded indoor spaces, we can plug that info into a simulation and see how many would likely get sick if, say, we were allowed to go drinking in bars without wearing masks.

As is the case with weather, it would be impossible to forecast every pathogenic storm that might lurk on the horizon. But, a centralized operation could show how an existing disease might spike in the next week or month, and assign it a threat level based on how dangerous it looks. If case counts climbed to the next rung on the ladder, it would trigger the implementation of preplanned mandates, like sending bar patrons out to the patio or entirely shutting down businesses, to keep the outbreak from surging out of control.

That kind of clear, uniform messaging "would help support the kinds of trillion-dollar decisions we are making right now," Rivers says. Such information can save lives. Computer simulations released in May 2020 by Columbia University suggest that if stay-at-home actions had been imposed one week earlier—on March 8 instead of March 15—the US could have avoided some 35,000 COVID-19 deaths.

Such a setup could also keep tabs on our readiness for a spike. Beth Cameron, the former senior director for the National Security Council's Directorate for Global Health Security and Biodefense, imagines that the monitoring center could investigate crucial metrics such as available ICU beds. "We're not just mapping the hurricane," she says, "we're also mapping the capabilities to manage the hurricane."

Cameron, who is now a VP for global biological policy at the nonprofit Nuclear Threat Initiative (the Trump administration dissolved the directorate about a year after she left), says that ensuring ready access to items like N95 masks and specimen-collecting swabs will help us respond quickly to future pandemics. Moreover, she points out, "A robust supply chain is not just about stockpiling, it's about being able to pivot." The government could identify companies capable of switching their production lines over to make needed equipment and agree on plans for doing so before they're needed.

While advocates for a national modeling center know that funding levels rise and fall as presidents and legislators come and go, they say creating a centralized agency is the best way to guarantee readiness for outbreaks. Countless unknown threats loom on the horizon. When the next one hits, we'd best know how to get ahead of its path of destruction.

GOODS

FALL 2020

PG 22

MECHANICAL PUZZLES » MAGIC TRICKS » CAVING GEAR » WILDLIFE CAMERA » ESSENTIAL FLASHLIGHTS

PHOTOGRAPHS BY *TRAVIS RATHBONE*

CRAVE

tongue twister

BY *STAN HORACZEK*

MYSTERY FLAVORS HAVE multiplied on store shelves of late. Companies tempt consumers into guessing obscure tastes in special editions of everything from chips to cookies. But at least one cryptic bite's profile remains under wraps: Laffy Taffy debuted its White Mystery Airhead in 1993, and the monochrome concoction continues to baffle.

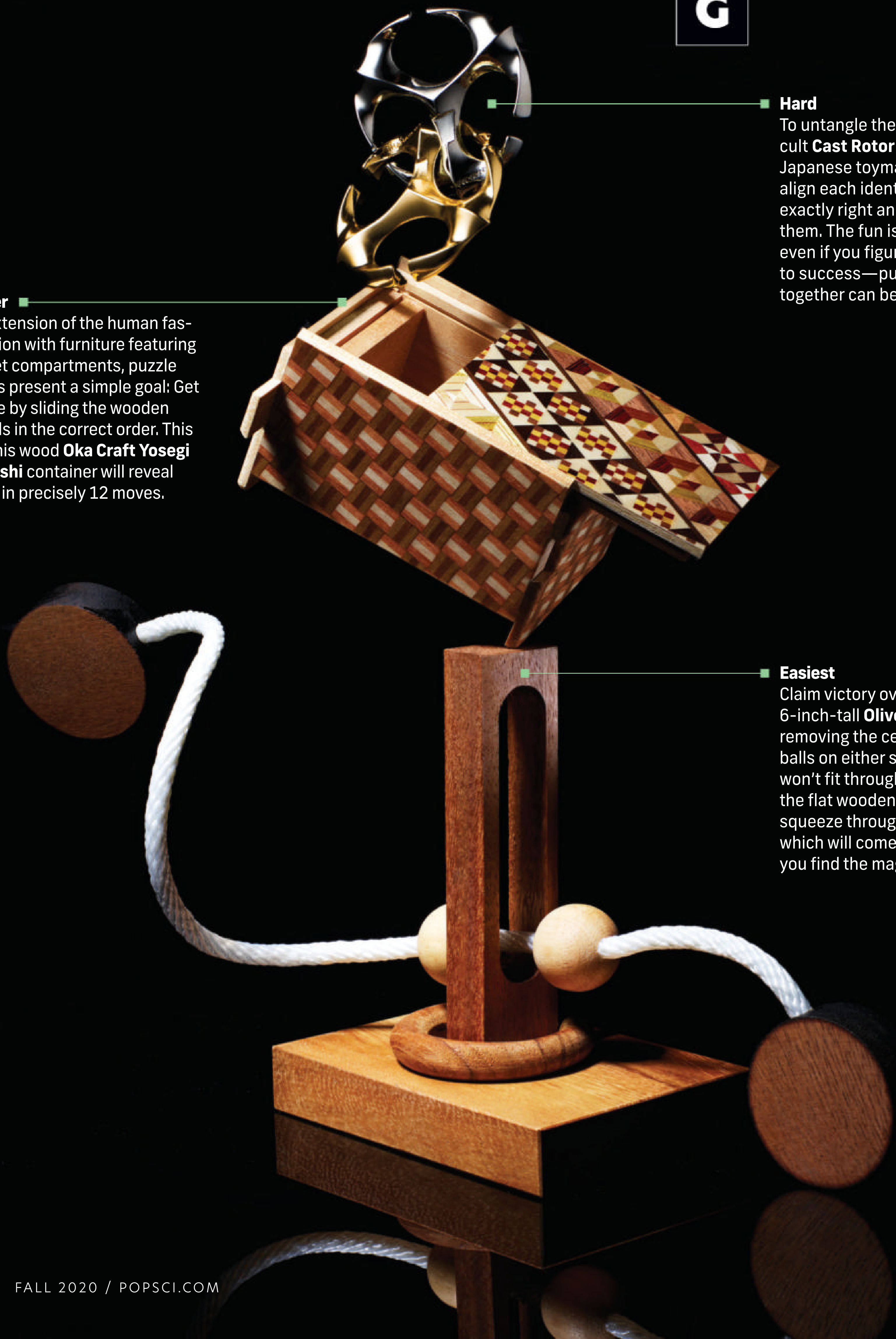
The candymaker receives heaps of fan theories every day—from tart lemon to smooth vanilla—but no one has gotten it right. Today, only a few dozen people know the secret identity; the rest of us have to settle for simpler certitudes. The tang of citric acid makes White Mystery undeniably fruity, and a mixture of sugar and corn syrup adds ample sweetness. The absence of color, however, is the curveball: It deprives the brain of the visual cues that can help taste buds determine the source and the intensity of a given zing.

RANKED

enigma machines

THE RUBIK'S CUBE GETS ALL THE ATTENTION, BUT THE COLORFUL TOY ISN'T THE ONLY BAFFLING MECHANICAL PUZZLE OUT THERE. HERE, YOU CAN FIND THE RIGHT LEVEL OF CHALLENGE TO MATCH YOUR SOLVING SKILLS.

BY *JOHN KENNEDY*



Hard
To untangle the extremely difficult **Cast Rotor** problem from Japanese toymaker Hanayama, align each identical zinc piece exactly right and then separate them. The fun isn't finished even if you figure out the path to success—putting it back together can be just as tricky.

Easier
An extension of the human fascination with furniture featuring secret compartments, puzzle boxes present a simple goal: Get inside by sliding the wooden panels in the correct order. This agathis wood **Oka Craft Yosegi Kuzushi** container will reveal itself in precisely 12 moves.

Easiest
Claim victory over the roughly 6-inch-tall **Oliver String** by removing the center ring. The balls on either side of the spire won't fit through the gap, and the flat wooden circles can't squeeze through the doughnut, which will come off only when you find the magic setup.

Clean your hands.
Clean your phone.
Stay healthy.

It only takes liking one Instagram post, answering a phone call, or sending a single tweet to transfer all the bacteria you've touched straight to your phone. It's the third hand you never wash, and when it isn't sanitized regularly, these germs can make you sick.

A 10-minute cycle in PhoneSoap kills 99.99% of all harmful viruses and bacteria on your phone. Stay happy and healthy by sanitizing your phone along with your hands, as the two are inseparably connected.
Save 10% with code POP10 at phonesoap.com

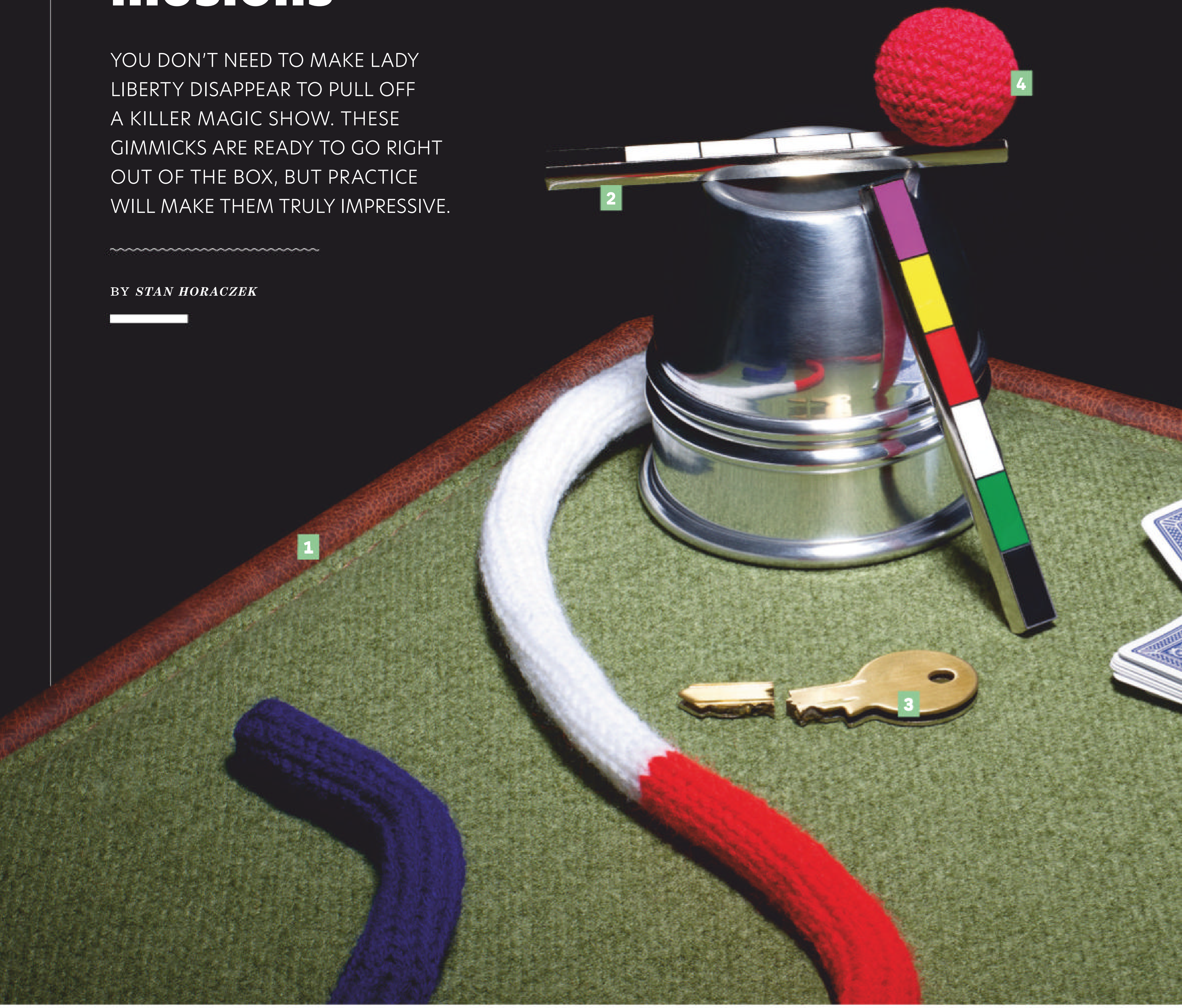
PHONE**SOAP**

STARTER KIT

they're called illusions

YOU DON'T NEED TO MAKE LADY LIBERTY DISAPPEAR TO PULL OFF A KILLER MAGIC SHOW. THESE GIMMICKS ARE READY TO GO RIGHT OUT OF THE BOX, BUT PRACTICE WILL MAKE THEM TRULY IMPRESSIVE.

BY *STAN HORACZEK*



1 Magic carpet
The 21.5-by-13-inch padded **Vanishing Inc. Deluxe Close-Up Pad** provides a comfortable surface for practicing and performing routines. The textured synthetic wool deadens noise that could betray sleight-of-hand movements in some close-up tricks.

2 Bar trick
By palming half of the multicolored **Magic Makers Sizzle Sticks**, deft illusionists can appear to change the rods from all red to black and white—and back. At 3.75 inches long, the nickel-plated props fit easily in a pocket for impromptu shows.

3 Key master
Skilled practitioners can seemingly chomp off part of the **Geraint Clarke Key Bite**, then spit it back into place thanks to an elastic band that connects both halves. One side is nickel and the other is brass, so it can mimic almost any door opener.

4 Sneaky spheres
A classic gimmick, **Murphy's Cup and Balls** lets quick-handed performers "teleport" wool orbs between aluminum containers as they slide them around a table. The roomy 3.3-inch-wide vessels help beginners avoid missing an orb and giving up the bit.

5 Stacked deck
Subtle markings at the top left and bottom right of each of the **Ellusionist Cohort Cards**' backs reveal the value and suit to help magicians look like mind readers. A thin yet stiff paper stock makes them tougher and lighter than a standard deck, for smoother shuffling.

6 String theories
The **Rainbow Ropes Remix** begins with a trio of strands that appear to be the same length. In reality, sliding knots connect two shorter ropes to a 3-foot section. With a little showmanship, viewers will believe they've morphed into a single, multicolored string.

into the depths

PROFESSIONAL CAVING MEANS ENTERING A WORLD MORE DANGEROUS THAN ANY WELL-TROD TOURIST CAVERN. THIS BURLY GEAR WILL KEEP YOU SAFE AS YOU VENTURE INTO THE DARK.

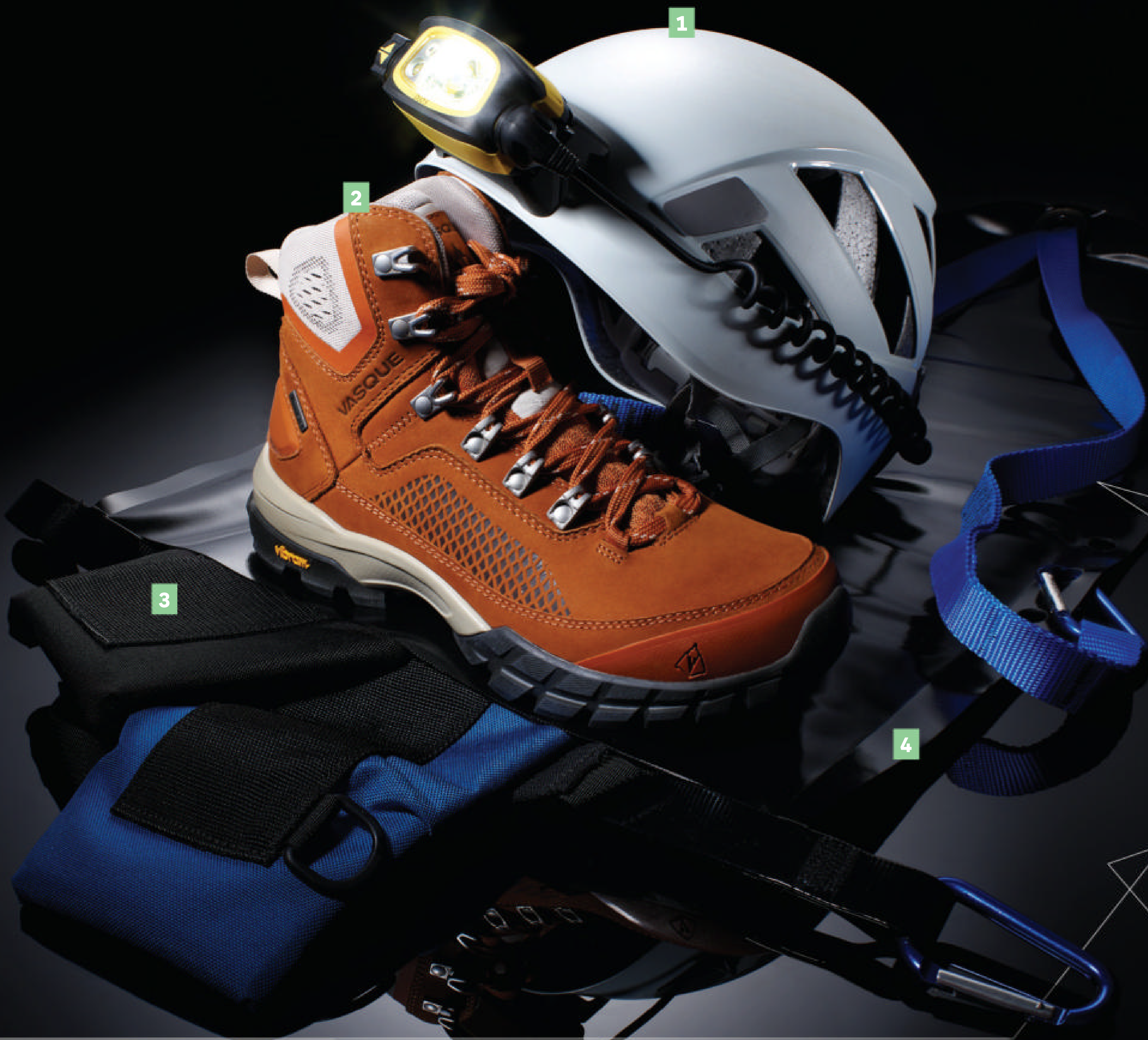
BY *ROB VERGER*

1 Headgear
The tough thermoplastic shell on the 12-ounce **Petzl Boreo Caving helmet** will protect the top and sides of your noggin from bumps against hard rock walls. An integrated mount provides a secure spot for a **Petzl Duo S headlamp** to illuminate your path.

2 Footwear
Floors can be slick with running water. Tacky Vibram rubber outsoles on **Vasque's Talus XT GTX boots** give you traction on muddy surfaces, while Gore-Tex membranes keep that H_2O at bay. A 2-millimeter-thick leather upper guards your feet.

3 Joint protection
Wriggling through tight spaces is necessary in most caves—and tough on your knees and elbows. Pads from **Gonzo Guano Gear** feature neoprene cushioning to shield your bony bits and durable polypropylene webbing that conforms to your body.

4 Backpack
Losing your food, water, or backup light sources deep underground can be deadly. The **Swaygo Pit Pack**'s slick nylon-polyurethane shell resists tearing, and its roll-down closure forms a waterproof seal that'll keep your stuff dry even when totally submerged.



gravity defyer
MEDICAL TECHNOLOGY CORPORATION

LIVE LIFE WITHOUT PAIN

Plantar Fasciitis • Arthritis • Joint Pain • Heel Spurs • Back & Knee Pain

PATENTED VERSOSHOCK® SOLE

SHOCK ABSORPTION SYSTEM

> *"I've had lower back pain for years. Walking in these shoes was life changing for me. I feel like I'm walking on air."*
>
> *– Bill F.*

85% LESS KNEE PAIN

91% LESS BACK PAIN

92% LESS ANKLE PAIN

75% LESS FOOT PAIN

*Results of a double-blind study conducted by Olive View UCLA Medical Center.

Enjoy the benefits of exercise *with proven pain relief.*

- ✓ Ultimate Comfort
- ✓ Renewed Energy
- ✓ Maximum Protection
- ✓ Improve Posture

G-DEFY ION *$155*

X-WIDE WIDTH AVAILABLE

Men Sizes 7.5-15 M/W/XW

- Black	TB9025MBB
- Red/Gray	TB9022MRG

Women Sizes 6-11 M/W/XW

- Black/Blue	TB9022FTL
- Gray/Teal	TB9022FGU

$30 OFF YOUR ORDER

Promo Code MC9JMJ4

www.gravitydefyer.com

Expires December 31, 2020

Free Exchanges • Free Returns

100% Satisfaction Guaranteed

Call 1(800) 429-0039

Gravity Defyer Corp.
10643 Glenoaks Blvd. Pacoima, CA 91331

A+ Rating BBB ACCREDITED BUSINESS

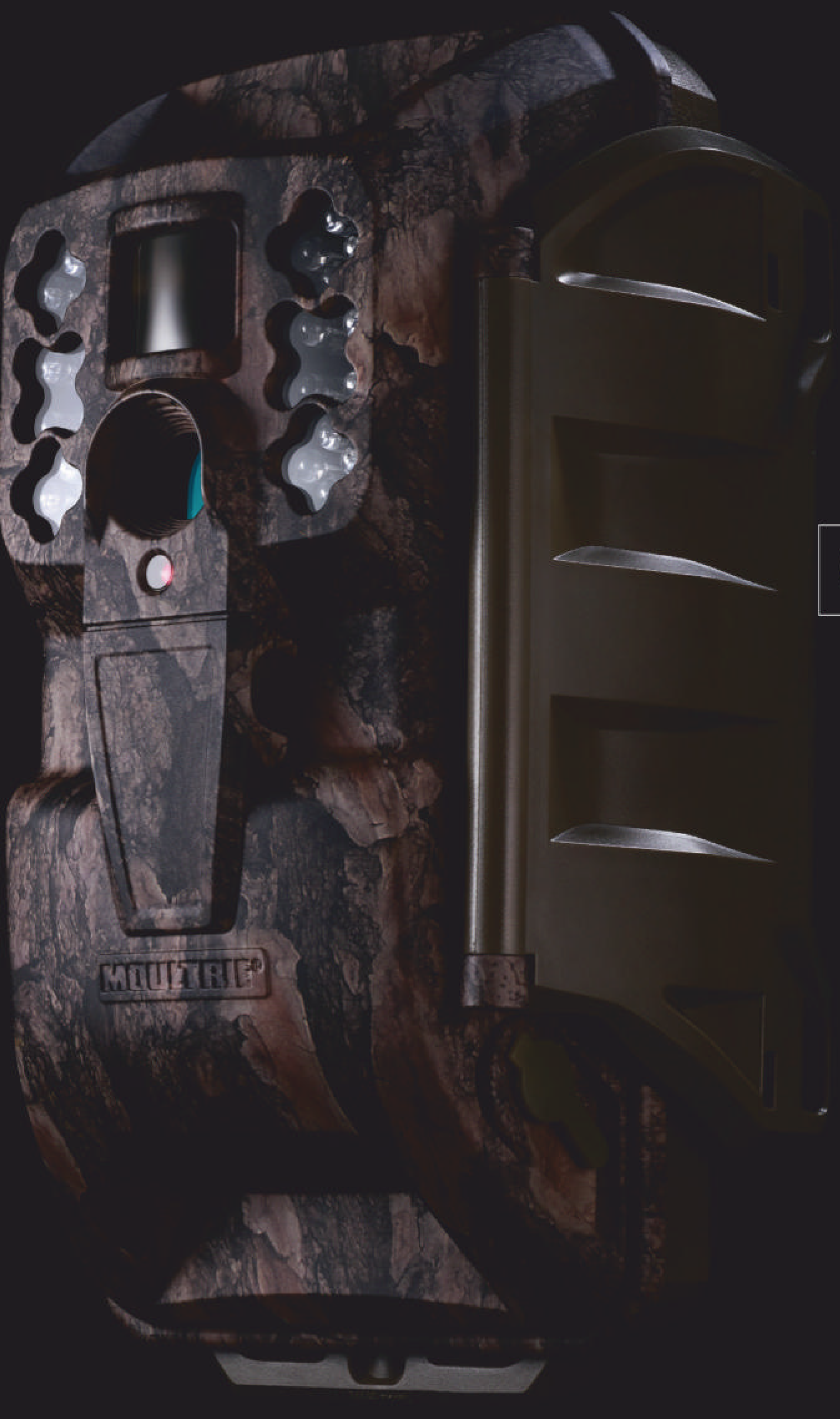
VersoShock® U.S Patent #US8,555,526 B2. This product has not been evaluated by the FDA. Not intended to treat, cure or prevent any disease. $30 off applies to orders of $100 or more for a limited time. Cannot be combined with other offers. 9% CA sales tax applies to orders in California. Shoes must be returned within 30 days in like-new condition for full refund or exchange. Credit card authorization required. See website for complete details.

HOW IT WORKS

night watch

BY *PURBITA SAHA*

AFTER DARK, YOUR BACKYARD COULD transform into a buffet for elusive critters like foxes, owls, and even black bears. Whether your home is near suburban woods or a swampy jungle, a **Moultrie XA-6000** camera will capture the evidence in HD. The gadget links with a phone app that'll let you know when something is afoot. Here's what's going on under its weather-resistant shell.



1 Find a good perch
To mount the 8-inch-tall device, hang it by its nylon strap some 3 feet off the ground, giving the wide-angle lens an ideal perspective. The AA batteries will provide power 24/7 for around 12 weeks.

2 Wait for evening
When an onboard infrared sensor detects motion within 80 feet and a temperature warmer than the air, it activates a night-vision camera. It then shoots video or 16-megapixel photo bursts.

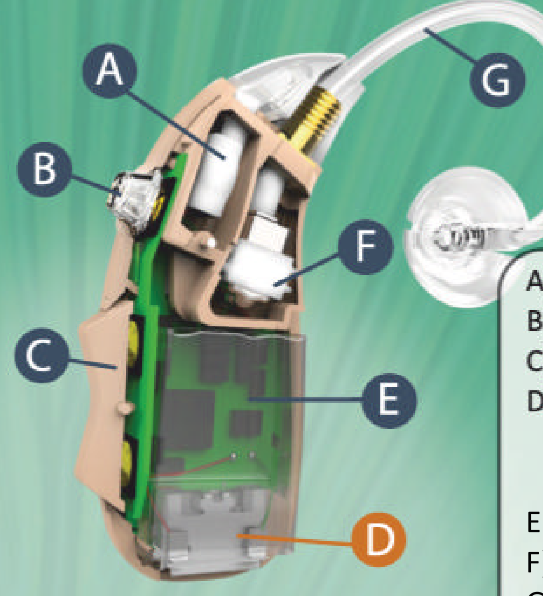
3 Check your phone
A pair of cellular antennas uploads the files to cloud-based storage software. An algorithm automatically tags them by season, moon cycle, and subject—like turkeys, bucks, or does.

HearClear GO™ Rechargeable Digital Hearing Aid Technology Only $199!*

(*Each when you buy a pair)

Enjoy this **fantastic, limited-time sale price** on our newest member of our affordable rechargeable hearing aids family!

As Seen On TV!



A) Microphone
B) Program Button
C) Volume Control
D) Magnetic Charging Port & Rechargeable Battery
E) Digital Processor
F) Receiver (Speaker)
G) Sound Tube

5 Star Reviews! ★★★★★

Couldn't Be Happier!
"So happy with this purchase. Can finally hear conversations again. Thanks guys for making an affordable hearing aid possible."
- *Nancy V.*

GO Features!

- ☑ Digital sound processing chip provides **crystal clear sound and makes speech easier to understand** with less feedback than old analog technology
- ☑ Don't worry about replacing batteries! **Full Charge Gives 16 Hours of Use! (Free Charging Station Included)**
- ☑ Automatic Noise Reduction and Feedback Canceler
- ☑ **100% Money Back Guarantee**

Telecare Convenience!

No costly professional appointments needed! With our free telecare, you can call our friendly and caring staff from the comfort and safety of your home to discuss your hearing care. You'll enjoy ongoing assistance to help you achieve the best hearing experience with your hearing aids!

★ HearClear hearing aids have been clinically proven to show **significant improvement in speech understanding**. (University of Memphis, 2018)

Easy.
Affordable.
Rechargeable Digital Hearing Aid - For Only $199!*

We're excited to introduce you to the most affordable member of our rechargeable hearing aid family: the HearClear GO! Our new HearClear GO Rechargeable Digital Hearing Aids feature **advanced digital technology** at an unbelievably affordable price! The GO utilizes the key technologies of high-end digital hearing aids while leaving out fancy bells and whistles that increase cost and require expensive adjustments. With the GO, **you'll hear more clearly while saving a lot of money!**

FREE
Charging
Station!

Your lightweight and discreet GO hearing aids work at a fraction of the cost of name-brand hearing aids, and they're amazingly convenient! With the GO's included charging station, you won't have to keep buying and replacing tiny hearing aid batteries, and the GO is pre-programmed for most mild to moderate hearing losses—no costly professional adjustments needed. **They're shipped directly to you and help you hear better right out of the box. Simply take them out, put them in, and GO!**

You can spend thousands on an expensive hearing aid or you can spend just **$239** for a hearing aid that's great for most mild to moderate hearing losses **(only $199 each when you buy a pair – hear up to 3 times better than wearing just one).** We're so sure you'll love your hearing aids we offer a **100% Money Back Guarantee - Risk Free** if you are not satisfied for any reason.

FOR THE LOWEST PRICE CALL!

1-888-352-1081

Use Coupon Code: **PZ9**

***Only $199 Each When You Buy A Pair!**
(Coupon Code & Price Valid For A Limited Time Only)

Questions?

Call Us!

Advanced Affordable Hearing™
Affordable Quality Since 1996!

MONEY BACK 100% GUARANTEE | RISK • FREE • Trial | FDA REGISTERED | US Company Owned And Operated | A+ BBB ACCREDITED BUSINESS

Visit and Save: **www.AdvancedHearing.com/PZ9**

CHOICE

the bright stuff

WHEN YOU REALLY NEED TO NAVIGATE THROUGH DARKNESS, YOUR PHONE'S WIMPY FLASHLIGHT JUST WON'T CUT IT. THE REAL DEAL WILL LAST LONGER AND SHINE BRIGHTER.

BY *ROB VERGER*

COAST
Fenix LR40R
ML300L
MAGLITE
ONTARIO, CA. USA

◂ **For charging**
The **Coast Polysteel 600R** has two possible power sources: four AA batteries or a 2,200-milliampere-hour rechargeable cell that can also power up other essential gadgets via its built-in USB port.

For huge spaces ▸
A junk-drawer flashlight's brightness measures in the hundreds of lumens. But the **Fenix LR40R** can produce a ridiculous 12,000 lumens, enough to highlight objects up to 2,500 feet away.

For long nights ▸
The 14-inch **Maglite ML300L 4D** can cast beams for up to 18 straight days without overheating. An air-based temperature management system helps it stay cool, so it'll keep going strong.

For everyday carry ▼
A flashlight in your closet isn't any good when you're away from home. The 6.5-inch-long **5.11 Tactical Rapid PL** device easily slips into a bag and has a range of 230 feet. It's also fully waterproof.

◀ **For your health**
The light at one end of the **VSSL First Aid** unit will burn for as long as 40 hours, but the real payoff is inside its aluminum tube: a rolled-up medical kit featuring key items like Advil, burn cream, and bandages.

For blackouts ▼
Sometimes you need to find light fast. Fluorescein and luminous powder in the **Pelican 3310PL**'s shell make it glow an eerie green so you can quickly spot it in a backpack or darkened room.

◀ **For your pocket**
At a scant 1.2 ounces, the **SureFire Sidekick** won't overburden your keyring. Click the single button to cycle through its power levels, maxing out at five times brighter than a typical smartphone light.

SAVEUR SELECTS® VOYAGE SERIES STAINLESS STEEL COOKWARE

18/10 TRIPLY STAINLESS STEEL | RIVET-LESS INTERIOR
SIGNATURE STAY-COOL HANDLES

macy's amazon THE HOME DEPOT wayfair TOUCH OF MODERN

saveurselects.com

SAVEUR Selects® is a registered trademark of Bonnier Corporation and used under license

SAVEUR
SELECTS®

NEW

RECHARGEABLE Digital Hearing Aid

Introducing the *VOLT* from MDHearingAid...

What's New

A digital, rechargeable hearing aid that's every bit as good as the ones you'll find at expensive clinics, but at a fraction of the price.

MD VOLT
Never Change a Battery Again

Buy One... Get one FREE

~~Reg $599.99~~

Only $299.99

Each when you buy a pair

FDA REGISTERED

VOLT Features

- Advanced Digital Technology
- Feedback Cancellation - NO Whistling
- Dual Directional Microphones
- Medical Grade Quality
- No Prescription Needed
- Unparalleled 24/7 Support

Nearly invisible...

No one will know you're wearing it

Doctors Are Tired of Patients Wasting Money at Over-Priced Clinics

Best Value ★★★★★
"...this product is just as effective (if not more) than traditional overly-priced hearing aids. I will be recommending MDHearingAid to my hearing-impaired patients." **– Dr. Chang**

Excellent Quality-to-Price Ratio ★★★★★
"Quite impressive in its performance... an excellent quality-to-price ratio, and I would highly recommend it to my patients with hearing loss." **– J. May, MD**

MDHearingAid®
DOCTOR DESIGNED | AUDIOLOGIST TESTED | FDA REGISTERED

BBB A+ RATING ACCREDITED BUSINESS

The new rechargeable VOLT incorporates advanced digital technology at an outstanding price.

We include the same high-quality digital processors as hearing aids costing $2,400 or more but eliminate the complex components not needed by 95% of the people with hearing loss. **PLUS... we cut out the middleman.**

Compare it to other rechargeable hearing aids and you'll find only VOLT has ***Feedback Cancellation*** and ***Dual Directional Microphones*** for superior performance.

Plus, we have ***24/7 Technical Support*** and a ***100% Money-Back Guarantee*** to ensure you're completely statisfied! No other company provides such extensive support.

Did you know most people who use one hearing aid really need two?

The brain processes signals from both ears for clarity & balanced sound so if you have hearing loss in both ears, your brain has to process two different sound and clarity levels.

SHOP AT HOME!
Skip the Clinic with Remote Care

RISK-FREE MONEY-BACK GUARANTEE

Hear Better Or Your Money Back!

Try MDHearingAids risk free with a 100% money-back guarantee for 45 days.

SATISFACTION 100% GUARANTEE

Call 1-800-811-3385 Today!

or visit www.MDVolt.com

Be sure to enter offer code **KD39** to receive

FREE SHIPPING!

POPULAR SCIENCE

MYSTERIES

FALL 2020

PHOTOGRAPH BY
THE VOORHES

38 SHINING LIGHT ON THE DARKEST COSMIC SECRETS

46 DO MEGA-SHARKS SWIM OUR OCEANS?

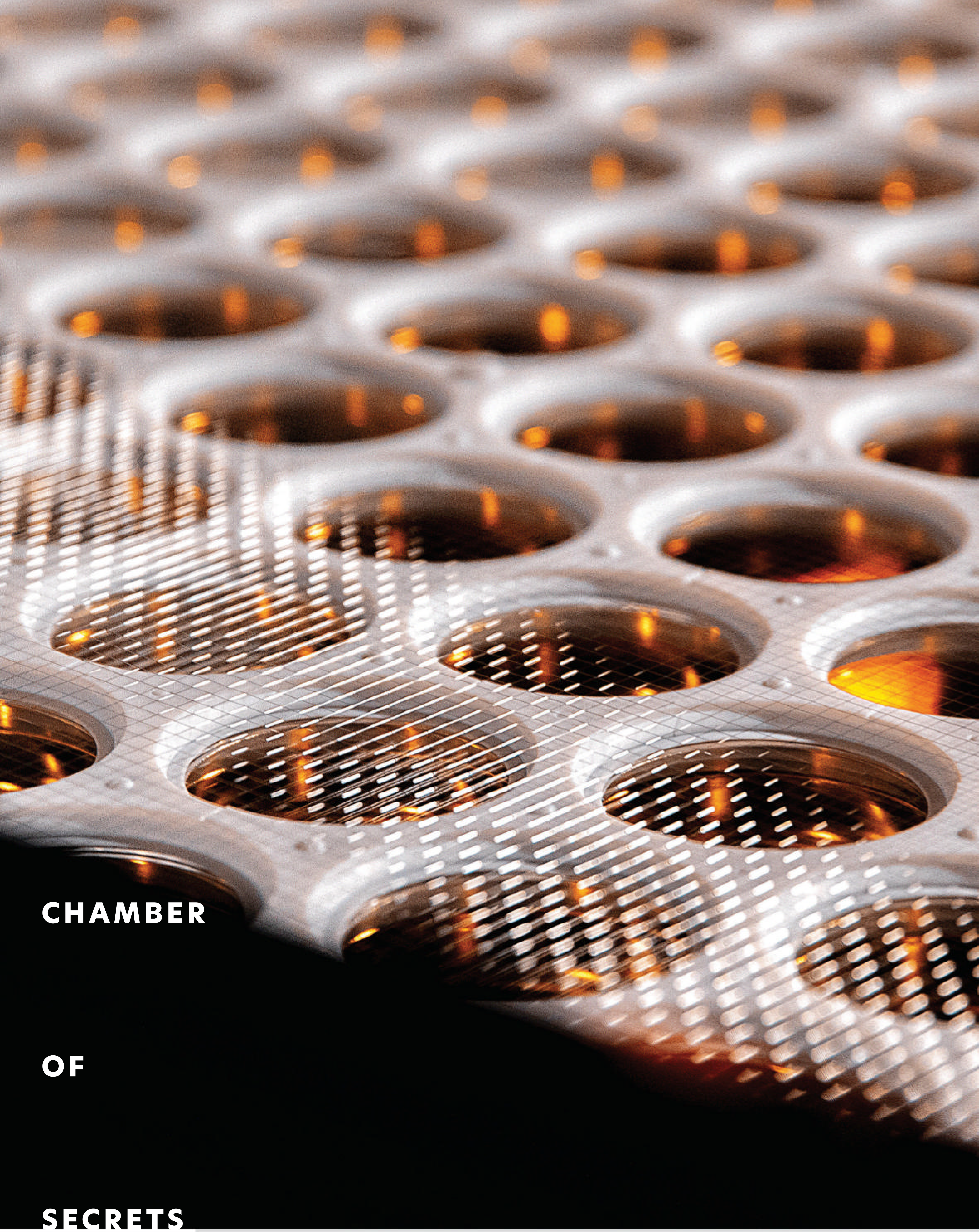
52 ACID TRIPS ARE MOST HEALING WHEN HOLY

60 HOW TO STOP SWARMS OF BEE THIEVES

66 HIDDEN WORLDS, RIGHT HERE ON PLANET EARTH

78 REVEALED: WHY HUMANS SEE GHOSTS

88 A NEW WAY TO SPY METHANE CULPRITS



CHAMBER OF SECRETS

Our latest shot at spying dark matter—and thus revealing the makeup of the universe—sits nearly a mile underground

By Ryan Bradley

THERE WAS A PAUSE, JUST BEFORE THE CAGE DOORS CAME RATTLING CLOSED AND WE BEGAN OUR 15-MINUTE DESCENT 4,850 FEET INTO THE EARTH.

WE WERE PACKED IN TIGHT: a crew of some 30 physicists, engineers, biologists, and—mostly—miners. Ex-miners, actually. This hadn't been an active mine for 18 years. The guy working the lift let the winch operator above us know that the cab was full, that we were a go. For a brief, delirious moment, suspended at the top of what was once the largest, deepest gold mine in North America, everything went quiet. Somewhere overhead, the frigid South Dakota winds whistled faintly, whipping through the Black Hills on this February day. A reminder of everything, the whole world we were leaving, as we began to drop.

And drop.

And drop.

The cage moved slowly and steadily, covering about five feet a second. We passed openings to shallower floors, dark and dripping with water. Biologists worked a few of these, scraping up bacteria from the muck, studying extremophiles to consider life-forms that might exist on other planets. An epic mystery, sure, but our destination was farther below: floor 4850 in the former Homestake Mine in Lead, outside of Deadwood, South Dakota, now the Sanford Underground Research Facility, or SURF. Here physicists from around the globe are trying to solve a puzzle more fundamental than life itself. Namely, what is the universe mostly made of?

Protons, neutrons, electrons—these are familiar to us. Elementary, even. We have also accounted for the weirder, smaller, subatomic stuff: the alpha and beta particles, the quarks, the neutrinos. Still, they don't add up. Not by a long shot. In order for existence to, well, exist, for galaxies to spin the way they do, for light from distant stars to bend the way it appears to, there must be quite a bit more out there than we've seen so far. The Standard Model, which classifies all elementary particles, accounts for just 16 percent of the universe's mass. That leaves another 84 percent. There are several theories as to what this remainder might be, but it all goes by the same name: dark matter.

The actual nature of dark matter is the subject of much debate. It could be one thing, one type of particle, sort of like a proton; or it could be several different things, like an electron *and also* a quark. Until we've found concrete evidence, we won't really know for sure. The purpose of the elaborate experiment this cage was descending toward is to find that evidence.

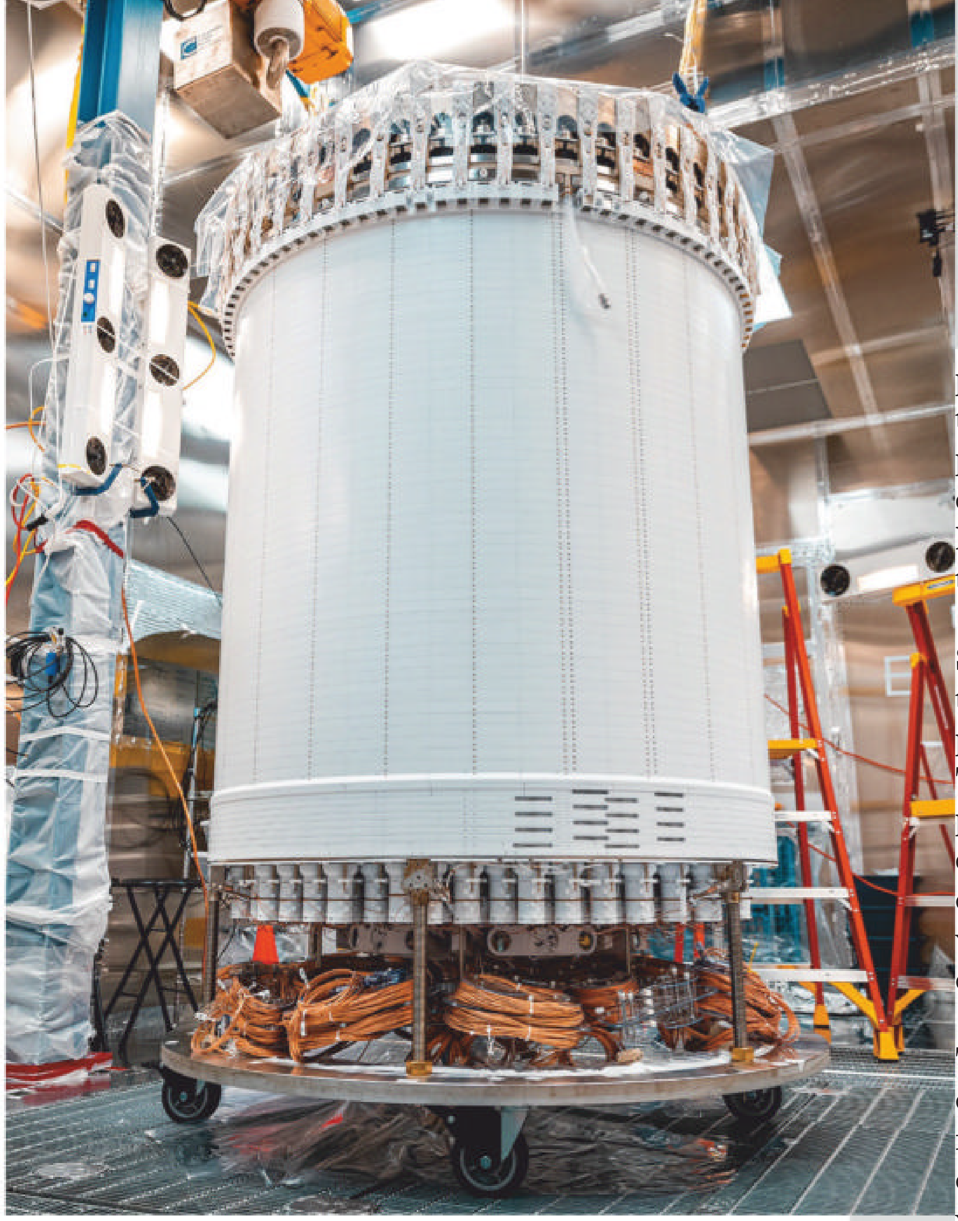
Here in the deep, tucked away from the humming interference radiating from everything around us, sits a wildly complex detector—let's call it a camera trap. It was designed and built to record the presence of the lead contender for dark matter, a physics unicorn called a WIMP, for weakly interacting massive particle. The endeavor includes at its heart a five-foot-tall tank filled with about one-quarter of the world's annual supply of liquid xenon. If a WIMP passes through, there's a chance it might glance off a xenon nucleus, which would emit a flash of light, a photon. Once the setup comes online—as soon as late 2020—it will run for five years. At that point the team will have either found proof of a particle that could be dark matter, or...not. The project is known as LUX-ZEPLIN, or LZ. LUX stands for Large Underground Xenon, ZEPLIN for ZonEd Proportional scintillation in LIquid Noble gases. It may well be our best shot yet at spotting a WIMP.

"This is the most exciting time for physics, because we still have the really big mysteries in front of us," says Kevin Lesko, a senior physicist at the Lawrence Berkeley National Laboratory, who coordinates the LZ project. In early 2020, the detector was in the final throes of assembly. Teams of six to 12 physicists and engineers worked in two shifts every day, from 8 a.m. to midnight, on an experiment that over five years has required experts in fields as diverse as photon detection and computer modeling, and from some 37 institutions across seven countries. "People like to say we know how to explain the universe. And now we're trying to figure out the big map of the universe," Lesko says of the massive collective effort.

The xenon tank is the crucial tool for filling in that map by determining what most matter might be. In October 2019, it traveled down the shaft via the cage in a highly orchestrated daylong event that left little room for error or jostling. A single slip and *crash*, years of planning, plus millions of dollars in research and development, would have gone down the mine shaft.

THE EVIDENCE OF DARK matter is everywhere, even though we've yet to glimpse the stuff itself. In 1933, Fritz Zwicky, a Swiss astronomer based at Caltech, noticed that the velocities of galaxy clusters seemed to make no sense: The gravitational forces of visible matter wouldn't be enough to keep the groupings from scattering. For these celestial bodies to congregate the way they do, some unseen mass (plus gravity) must be helping pull them together. In the 1970s, astronomers Vera Rubin and Kent Ford were studying the spirals of the Andromeda galaxy and found, to everyone's astonishment, that the stars at the outermost edges moved just as quickly as those at the center, violating Kepler's third law of

PREVIOUS SPREAD: MATTHEW KAPUST/SANFORD UNDERGROUND RESEARCH FACILITY



ABOVE: A tank filled with xenon awaits transport to its home in a former gold mine below Lead, South Dakota. LEFT: Mine carts transport new kinds of workers and equipment.

planetary (in this case, galactic) rotation, which holds that the objects revolving around a core should move more slowly as the distance from the middle increases. That they don't suggests that some farther-away mass influences these bodies. There are other clues out there, like the way light from remote stars bends on its journey to us, and the consistency of the cosmic microwave background, and the elliptical and spiraling shapes of galaxies. All this points to the existence of a great, nonluminous, unseen mass.

Peering out into space gives us a sense of the effect dark matter has on the form and appearance of our universe, but all that evidence is indirect, a shadow of a shadow. This invisible stuff will remain a mystery until physicists can observe the particle or particles that account for it, which they've been trying to do for about 30 years. Some experiments attempt to plot a chart that points to dark matter by searching out evidence of its decay through high-flying instruments like the Fermi Gamma-ray Space Telescope. They call this approach indirect detection.

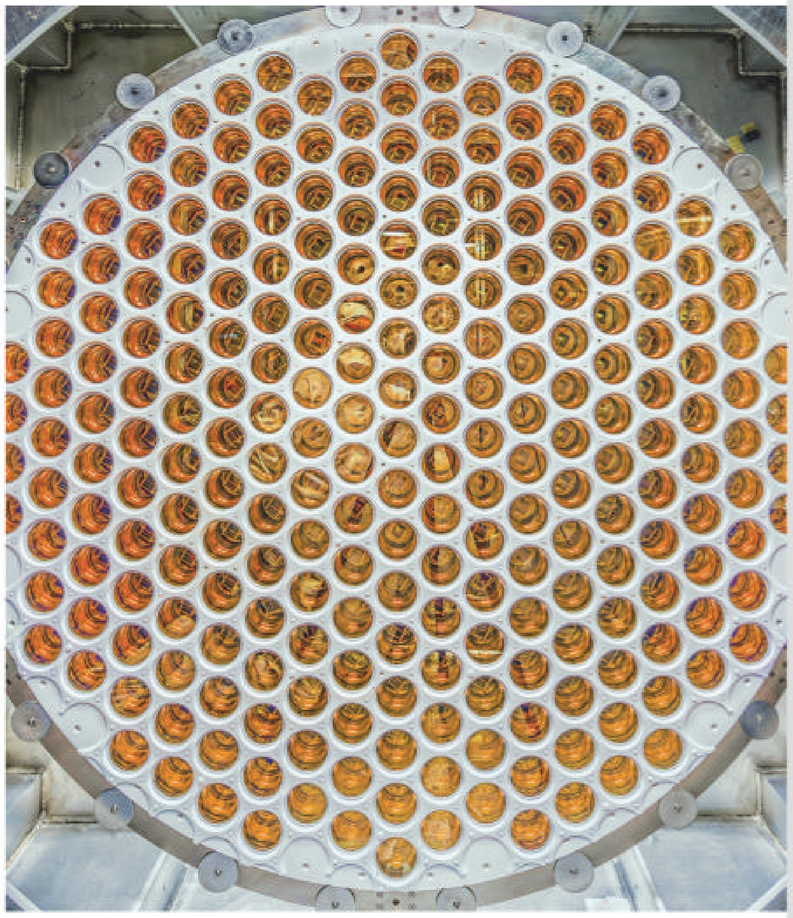
Other techniques instead try to create dark matter. Since 2012, physicists have been running experiments that could do just that—on the Large Hadron Collider particle accelerator at CERN, near Geneva, Switzerland. The efforts, collectively called ATLAS, smash together protons to mimic the circumstances of the big bang, when everything in our universe formed, including, theoretically, dark matter. By comparing the energy they know went into the accelerator with the measurements of what comes out, the scientists might prove its existence.

More often, dark matter sleuths want hard evidence. That is, they want to directly detect it. But again, no one is precisely sure what it is they're looking for. Aside from the WIMP, there is another potential culprit: a theoretical particle called an axion. If they exist, axions would help explain how neutrons, even those with charged quarks kicking around inside them, manage to remain neutral. They'd also be around one trillion times less massive than an electron, meaning trillions would fit in a space the size of a sugar cube. Physicists think the trick to spying them is speeding up their otherwise glacial decay into photons, which are relatively easy to spot. A detector built by a team at the University of Washington wields a huge and incredibly powerful magnet to hasten that pace, while a resonator tuned to the microwave frequency of the possible decay keeps watch.

Yet amid the broad field of dark matter makeups that

> "THIS IS THE MOST EXCITING TIME FOR PHYSICS, BECAUSE WE STILL HAVE THE BIG MYSTERIES IN FRONT OF US."
>
> —**KEVIN LESKO**

FROM TOP: NICK HUBBARD/SANFORD UNDERGROUND RESEARCH FACILITY; RYAN BRADLEY



LEFT: Physicists wire up a photon-detector array to transmit potential WIMP signals out of the xenon tank. ABOVE: The sensors of a single array; two of them peer into the vessel from above and below.

MATTHEW KAPUST/SANFORD UNDERGROUND RESEARCH FACILITY (2)

scientists have floated over the years—including candidates from primordial black holes to MACHOs (massive astrophysical compact halo objects) half the bulk of our sun—WIMPs have remained a primary target. If they're out there, they would neatly align with another popular notion in theoretical physics called supersymmetry, the idea that for every bit of mass we can see there is also a counterpart that is not luminous, the yin to its yang. If that idea's correct, what we've added up from everything covered by the Standard Model would be mirrored by the WIMP presence. The universe, unknowable and chaotic as it may seem, tends toward elegant solutions like this one. Or elegant solutions like this one tend to explain the universe.

Still, even within the world of WIMPs, questions remain. The particles might exist in a range of masses, from about one proton to 100,000 protons. One experiment, called SuperCDMS, is searching for wee-er WIMPs than the LZ. Based in a nickel mine in Ontario, Canada, it relies on six detectors made of silicon or germanium crystals; if a WIMP hits one and disturbs a crystal's electrons, the interaction will create vibrations, a signal that can be amplified. The rig runs at –450°F to cut out the noise generated by thermal energy. And it also sits deep underground—6,800 feet—shielded from the radioactivity of day-to-day life, the cosmic buzz coming off everything from stars to the soles of your Chuck Taylors.

There's another xenon-based WIMP detection attempt, an international effort located under Italy's Gran Sasso mountain—and aptly named XENON. The scientists involved announced in June 2020 that their experiment was registering extra background signals, which could wind up proving there are axions. Or it might be neutrinos. Or the result of contamination. As with much in dark matter, the data can seem to be on the brink of reality-shifting, but turn out to be nothing at all.

Lesko, who's been working on such subterranean experiments—including the LZ's smaller predecessor, LUX—for the better part of 30 years, explains why these efforts always happen so deep underground. Imagine, he says, "you're trying to hear a whisper. You do it in the middle of New York City, you're not going to hear it, there's just too much noise. You want to get away from our backgrounds—the cosmic rays and junk we're bombarded by would hide the very rare signals we're looking for." But here Lesko stops himself: The signal, the particle, "isn't necessarily rare, what's rare is the interactions with things we can observe."

The observational challenges beget a borderline obsession with eliminating every iota of potential interference. That's why, when Lesko would fly out to Lead (pre-pandemic, of course) to visit the mine-turned-lab for a week every month, a lot of what he and the crews would work on was keeping absolutely everything as exceptionally clean as possible. It's a difficult task anywhere, but it's absurdly so way down inside a tunnel carved into the rock.

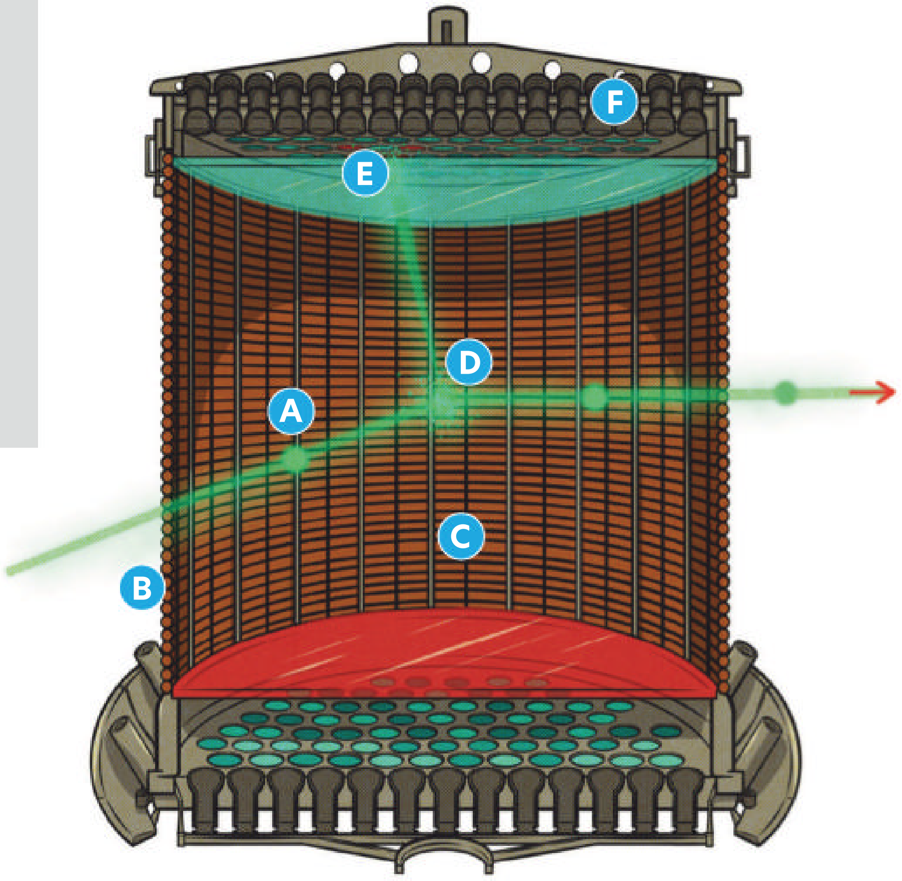
THE CAGE DOORS OPENED on level 4850, and we all marched out. Crews of scientists and staff piled into electrified carts—mine carts!—to travel a quarter-mile-long, unlit, dirt-floored passageway toward more distant labs. Closer to where the lift had delivered us, I exchanged my boots for a pair of very clean trail runners that never left this space. I wiped down my phone, pen, notebook, and hands and stepped across a sticky floor to remove any dust from the shoes, then down a long hallway that led to the room where the LZ was coming together. Through the doors came a long, high whistle that sounded like a terrible scream.

"That's the liquid nitrogen we're running through the pipes—it's loud!" yelled Aaron Manalaysay, a physicist at the Lawrence Berkeley National Laboratory, over the gassy wails. Manalaysay was down here with a crew of graduate students, working over several months to finish assembling all of LZ's thousands of component parts, which took up nearly all the room.

When the screaming died down, we walked through a set of double doors and into the space. I expected first to see the tank at the center of the LZ experiment, huge and gleaming. Instead there were rows of pipes and wires running from sensors to stacks of computers outside the container; a cryogenics panel for cooling the xenon

HOW TO SPOT DARK MATTER

The quest to capture proof of WIMPs, a lead candidate for the makeup of dark matter, sends the physicists behind the LUX-ZEPLIN experiment below ground. Nearly a mile down, background noise is minimal, but spying the particles still requires a rig looking for a very specific interaction.



A. Set a target
Dark matter particles, possibly WIMPS, surround and move through everything, the LZ included, even if we don't notice them.

B. Eliminate noise
To up their chances of spotting one, physicists buffer the WIMP trap with many layers, the innermost of which is a titanium tank.

C. Wait quietly
Nonreactive, some 11 tons of liquid xenon housed within the tank creates a placid space in which to watch for dark matter activity.

D. Interact!
Should a WIMP glance off the nucleus of a xenon atom, the collision will elicit sparks of energy: a burst of photons.

E. Grab the flash
Hundreds of 3-inch-wide photon detectors nestled into circles at the top and bottom of the structure amplify any activity.

F. Record the signal
The array converts the burst into electrons—data points that indicate the spot within the tank where the interaction occurred.

ILLUSTRATION BY MAXWELL ERWIN

gas to just below –163°F (the temperature at which it liquefies) and helping to lower background interference within the tank itself; plastic curtains draped around areas still undergoing assembly; air ducts and lockers and orange cones and caution signs. At the middle of all this sat a 20-foot-tall, curving stainless-steel structure: the first layer of the LZ's tank. This would be filled with 70,000 gallons of water to further buffer the inner xenon chamber—in a sense, a gigantic thermos.

Peering into a small, heavy, swung-open porthole revealed the inner sanctum, the xenon tank. Why xenon? It's extremely dense and, as one of the noble gases, it's inert. Most of the time, it doesn't react to most things it comes into contact with. It is, in other words, extremely quiet. So reactions within the element tend to stand out, which is exactly what you want when trying to spot a sudden flash that might end up proving the existence of dark matter. Inside this titanium vessel were photon detectors—the "cameras" in the trap: several hundred 3-inch-wide tubes honeycombed into two nearly 5-foot-diameter circles at the top and bottom of the huge canister.

We stepped back from the porthole and climbed a ladder to a mezzanine level midway up the outer tank, where Theresa Fruth, a physics research fellow at University College London, was working on the detectors. She was testing how they would function within the rest of the system. The tubes act as capture and amplification devices, she explained. When a particle, WIMP or otherwise, moves through the tank and hits the nucleus of a xenon atom, the result is energy, in the form of light: a photon, or more likely many. The arrays absorb these and convert them into electrons. Each one represents a data point—X, Y, and Z coordinates—that shows where

> **“ONCE YOU KNOW WHAT THOSE FEW BILLION EVENTS ARE, THEN YOU CAN KNOW, ‘AH, THIS IS SOMETHING.’”**
>
> *—MARIA ELENA MONZANI*

in the area an interaction is coming from.

The vast majority of the events will stem from the decay in the surrounding rock walls. "That will happen," Fruth said. "We don't care." Physicists know what those signals look like and can easily ignore them. Besides, one of the benefits of having such a huge amount of xenon, she explained, is that its outer edges—in addition to the tank itself, and the water, and the other tank, and the mile of earth above—act as a buffer. "If we go closer to the center, we get much quieter." This was the spot where they might find dark matter. Or where "we can reasonably search for a rare interaction."

A RARE INTERACTION, WERE it to happen inside the tank, could blip without anyone even noticing. The final trick, perhaps the trickiest of all, is to make certain that we do spot this flash of activity amid all the others. Once the LZ comes online, it will register approximately a billion interactions per year. This petabyte worth of data is the responsibility of Maria Elena Monzani. She works at the SLAC National Accelerator Laboratory at Stanford and manages the software and computing infrastructure of LUX-ZEPLIN.

Because no one has seen a dark matter interaction before, it's important to try to be sure about everything we have actually seen. Monzani coordinates the cataloging and modeling of all the "knowns" in order to make it easier for the unknowns to stand out. "We're going to have a few billion events, and dark matter will be a handful," Monzani says. "It's very important we understand what those few billion events are. Once you know that, then you can know, 'Ah, this is something.'"

Monzani oversees what is, in essence, an inoculation against the mind's urge to see things (patterns, particles) that aren't really there. She's got several platoons' worth of physicists spread around the globe, working on two data centers running full simulations of the LZ. They're calibrating the machine, the algorithms, and, yes, the humans. To calibrate a person, Monzani and her team churn out datasets from a simulation of the LZ tank, then, diabolically, add extra data that looks just like the real thing—a method called salting.

Monzani's crew drops in data that, say, looks like the energy a WIMP would leave in its wake. They know these markers are fake, but their analysts don't, thus creating a blind test to reduce the bias that may come about from physicists' very real desire to find an exciting interaction. When the trial run is done, Monzani's team reveals which of the signals were placebos. What's left is, in this case, the "real" ones created by the LZ simulation (they'll repeat the process when the experiment turns on and live data starts coming in). Everyone wants to find dark matter. Salting trains them to be honest.

Running simulation after simulation of the LZ systems became the bulk of the (CONTINUED ON PAGE 107)

ABOVE: The LZ's xenon tank slips into its housing. LEFT: The Black Hills flank Lead, South Dakota. BELOW: The crew watches as the tank lowers into the spot where it might finally nab dark matter.

NICK HUBBARD/SANFORD UNDERGROUND RESEARCH FACILITY (3)

MONSTER MYTH

MEGALODON

The notion of the megalodon continues to captivate humans. Could this giant, ancient shark still lurk on the ocean floor?

By ***Riley Black***

Illustrations by ***Esther van Hulsen***

LEGENDARY BEASTS OF THE *(NOT SO)* DEEP

IT'S GOT TO BE OUT THERE. It doesn't matter that *Otodus megalodon* has by all scientific accounts been extinct for more than 3 million years. The ongoing earthly presence of the enormous shark persists in our collective imagination thanks to rumors, legends, and summer B flicks.

Meg mythology often posits that the 50-foot predator has been hiding for epochs somewhere at the bottom of the ocean. It's a notion that's launched more than a few books and pseudo-docs, all hinging on the fact that most of the planet's nether waters are unexplored—and therefore rife with primo dens for enigmatic beasts. But based on what we know of the biological adaptations required for life down below, not many animals could pull off a deep-sea disappearing act. If megalodon is still out there (and that's a pretty big if), it's not what it used to be.

Fossil shark teeth got people hooked on the Meg long before paleontology took off in the early 19th century, when scientists started cataloging fossils with gusto. In 1835, Swiss naturalist Louis Agassiz described triangular, finely serrated teeth, which had been found worldwide since antiquity, as belonging to a "megatooth" relative of the great white.

Discoveries around the world—in locations as diverse as Panama, Japan, Australia, and the southeastern United States—piled up over time, but one particular find raised the specter of a Meg still swimming in the deep. In 1875, during an expedition for the Royal Society of London, the HMS *Challenger* dredged up 4-inch-long teeth from a depth of 14,000 feet near Tahiti. In 1959, zoologist Wladimir Tschernezky, who made a hobby of researching "hidden animals" like Bigfoot, estimated the specimens were just 11,300 years old. Other scientists have since dismissed this dating, but unscrupulous documentarians and curious amateurs still highlight the research as a hint that Meg might persist.

Save for the outliers found by the *Challenger*, the megalodon's fossil record indicates it was a shore-hugging creature, similar to its distant cousin the great white. "Remains generally come from coastal marine rock deposits formed in tropical-temperate areas," says DePaul University shark researcher Kenshu Shimada. The species's dietary habits further confirm a shallow lifestyle, with gnawed ancient whale bones showing Meg's preference for marine mammals. These air breathers had to break through the surface for oxygen, so paleontologists expect megalodon, like them, hung out near the shore.

The exact combination of factors that pushed the ancient shark into extinction is still murky. We do know that shallower oceanic zones were undergoing dramatic changes around 3.5 million years ago, when the giant disappears from the fossil record. Water was growing cooler, making marine mammals less abundant, and the newly evolved great white may have served as a nimble competitor for resources. But there's no way to prove definitively what did in the Meg.

The lack of certainty helps some maintain hope of finding one in the deep. Believers have at least one thing right: The bottom of the sea is an enigma. Even though satellites have mapped 100 percent of its floor, a low-resolution chart alone doesn't give us great insight into what actually lives there, says Louisiana Universities Marine Consortium Executive Director Craig McClain, who specializes in cataloging oceanic systems. While the idea of a deep-dwelling ancient creature is highly improbable, he says, the sliver of possibility is still tempting. Less imposing critters have indeed shown up unexpectedly; in 1938 biologists identified

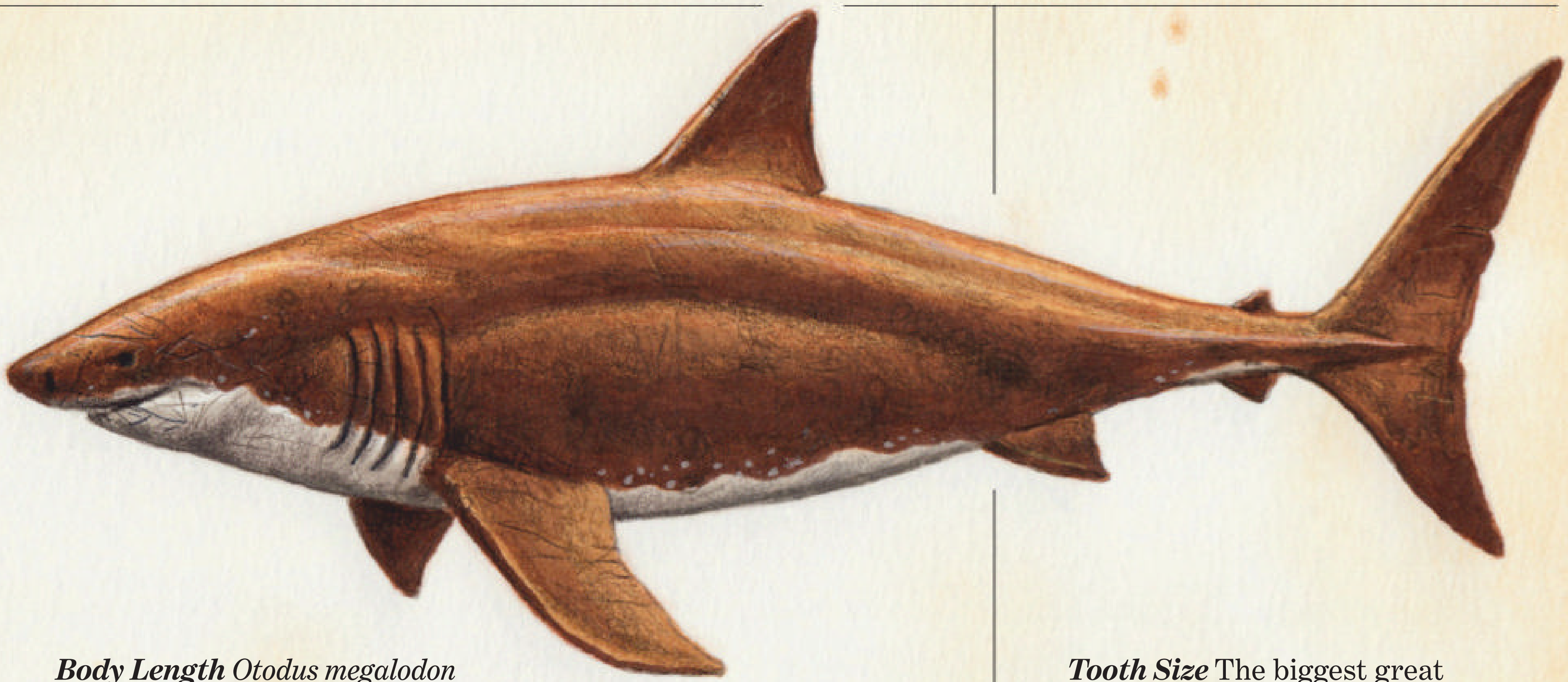
(CONTINUED ON PAGE 51)

A HISTORY OF THE MEGALODON

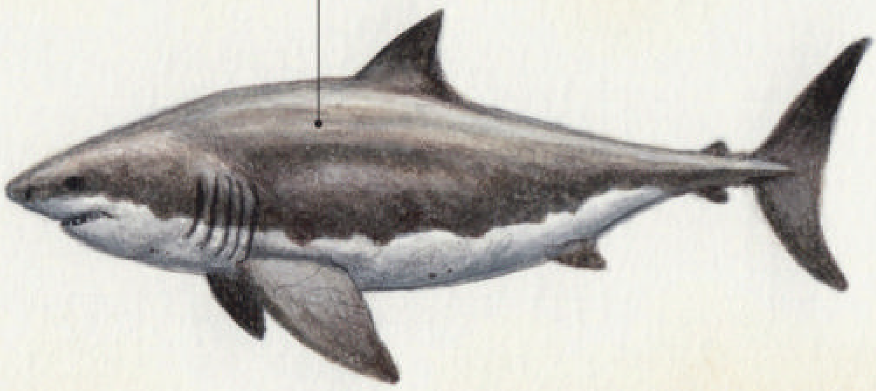
16 million years ago	*Otodus megalodon* evolves from an ancestral group of megatooth sharks—the last member of a line that began 60 million years ago.
10 million years ago	The shark spreads to coastal waters worldwide. Clusters of baby teeth near Panama suggest nurseries were close to shore.
5 million years ago	Great white sharks evolve, and likely compete with the massive Meg to eat the same marine mammals, such as whales.
3.5 million years ago	*Otodus megalodon* seemingly goes extinct around a time of upheaval, including cooling seas and a dip in the species it munched on.

WHAT MAKES A MEGALODON

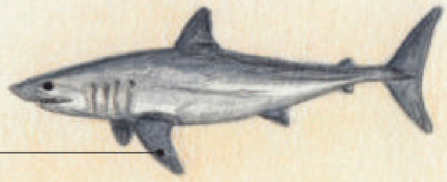
For decades *Otodus megalodon* has been depicted as an oversize great white. But thanks to new analyses of where it sits on the shark family tree, the predator scientists know now is very different from the *Jaws* star.



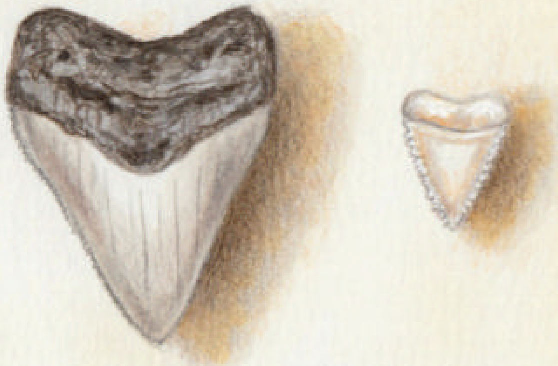
Body Length *Otodus megalodon* could grow to be about 50 feet long, more than twice the length of the largest great whites.



Body Shape Based on comparisons to other shark fossils, it's now thought that great whites evolved from the mako line, not from Meg.



Tooth Size The biggest great white teeth are about 3 inches long, while megalodon teeth stretch up to nearly 8 inches.



Tooth Shape A Meg's chompers have finer serrations than their modern cousins', which helped it to easily crunch through bone.

70 CE Pliny the Elder notes that large "tongue stones" found in the rock strata of Europe may fall from the heavens during lunar eclipses.

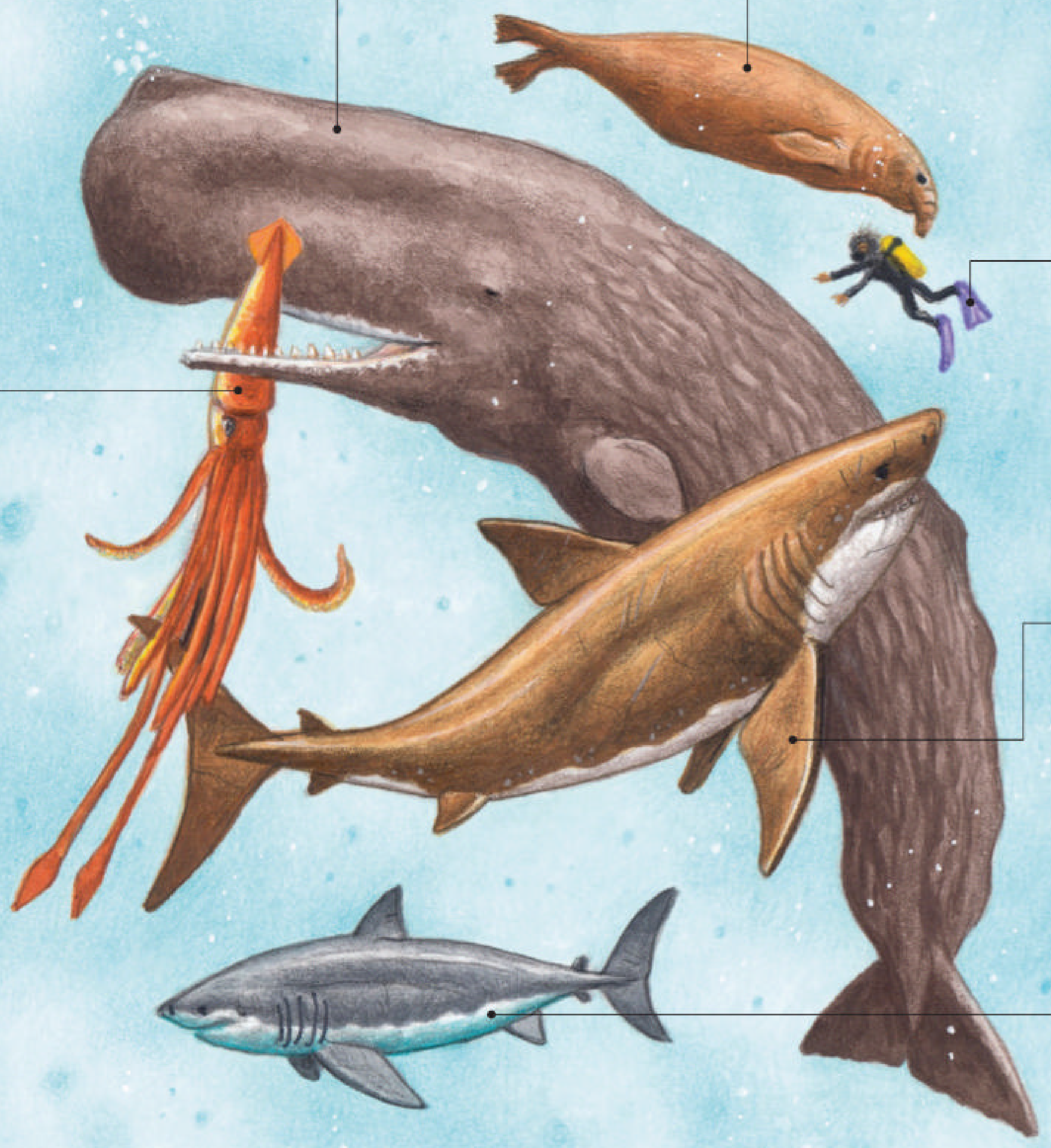
1666 Danish scientist Nicolas Steno dissects the head of a shark found off the coast of Italy and speculates that "tongue stones" are teeth.

1835 Swiss naturalist Louis Agassiz coins the name *Carcharodon megalodon* in describing a set of the creature's giant chompers.

1875 The HMS *Challenger* dredges up megalodon teeth from the deep sea near Tahiti, fueling speculation about the shark's survival.

OTHER OCEAN BEHEMOTHS

Megalodon was a massive fish, but it wasn't the biggest predator ever seen in the seas. We've adjusted our estimates of the shark's size over the years, but most experts now suspect it stretched about 50 feet long. Here's how it stacks up against some modern ocean meat eaters.



Giant squid, 43 feet
Found in every ocean on the planet, this mollusk is the world's largest known invertebrate.

Sperm whale, 62 feet
The biggest of the toothed whales can dive more than 7,000 feet in search of giant squid to eat.

Elephant seal, 20 feet
Pups are favorite prey of the great white, but fully grown seals are likely more similar to the critters Meg ate.

Human (for scale), approx. 6 feet
Given that diving tech dates back only to the 19th century, we're still relative newcomers to the underwater world.

O. megalodon, 50 feet
The largest predatory fish of all time, Meg was a relative of today's mako and great white sharks.

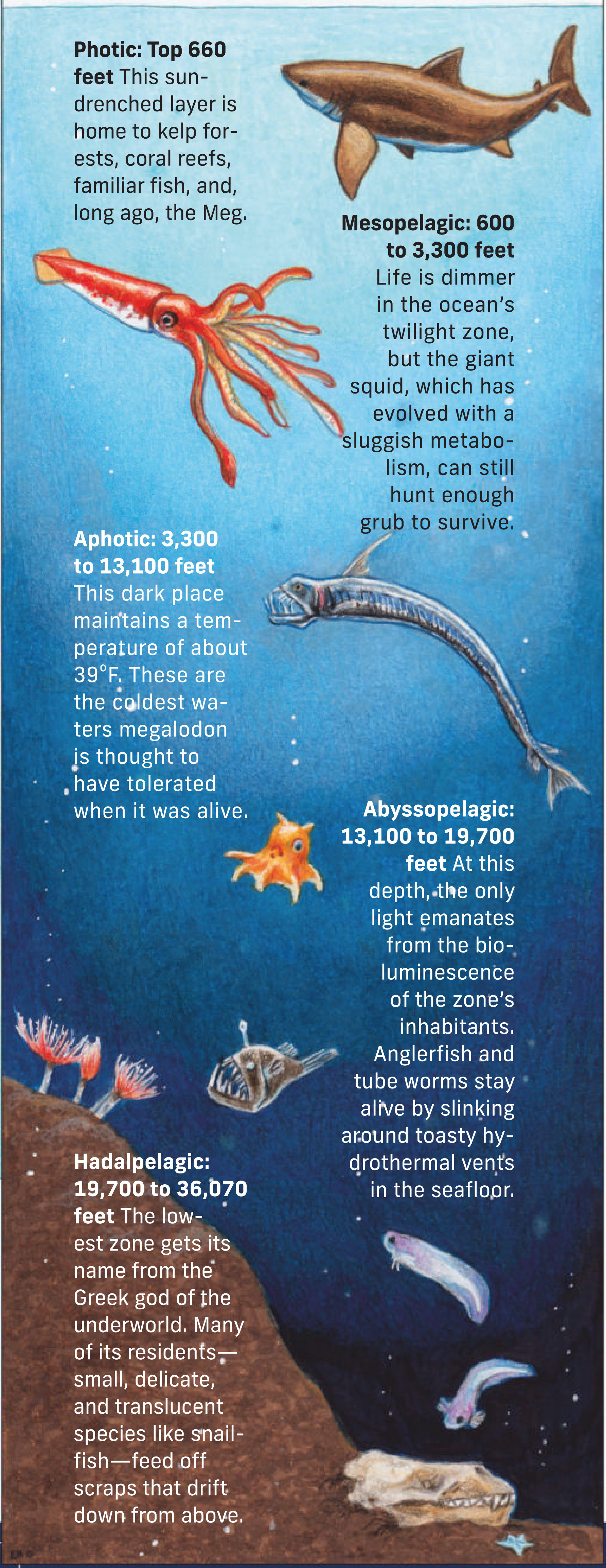
Great white, 20 feet
This *Jaws* star has taken the place of its distant cousin, the Meg, as the ocean's biggest bloodthirsty fish.

A HISTORY OF THE MEGALODON (CONT'D)

1909	1919	1974	2016
Researchers build a model of a Meg jaw that fits six standing adults—suggesting an 80-foot body. This is now considered oversize.	Fishers in Australia claim to see a massive shark eat multiple lobster pots. The legend eventually makes its way into megalodon lore.	Peter Benchley publishes *Jaws*, which plays with the idea that a prehistoric man-eater might lurk in the deep. The public is hooked.	After decades of debate on the specifics of Meg's family tree, the giant shark gets the new scientific name *Otodus megalodon*.

HOW LOW COULD MEG GO?

Our planet's waters get less hospitable the farther down you drop, and megalodon likely only scratched the surface. These are the ocean's five zones—and what can make a living in each.



Photic: Top 660 feet This sun-drenched layer is home to kelp forests, coral reefs, familiar fish, and, long ago, the Meg.

Mesopelagic: 600 to 3,300 feet Life is dimmer in the ocean's twilight zone, but the giant squid, which has evolved with a sluggish metabolism, can still hunt enough grub to survive.

Aphotic: 3,300 to 13,100 feet This dark place maintains a temperature of about 39°F. These are the coldest waters megalodon is thought to have tolerated when it was alive.

Abyssopelagic: 13,100 to 19,700 feet At this depth, the only light emanates from the bioluminescence of the zone's inhabitants. Anglerfish and tube worms stay alive by slinking around toasty hydrothermal vents in the seafloor.

Hadalpelagic: 19,700 to 36,070 feet The lowest zone gets its name from the Greek god of the underworld. Many of its residents—small, delicate, and translucent species like snailfish—feed off scraps that drift down from above.

(CONTINUED FROM PAGE 48)

a living coelacanth—a species of fish presumed extinct for about 65 million years.

If the megalodon were living in the dark, inky depths, though, it would have had to become a very different sort of creature—one we might not find nearly as cinematic. For one thing, Shimada says, its ravenous metabolism would need to fundamentally change. Preliminary geochemical analysis of isotopes in remains, which can help scientists estimate the body temperature of prehistoric organisms, indicates that megalodon was "warm-blooded" in the same sense as the great white. That predator's active ocean cruising generates enough body heat to keep it toastier than surrounding seawater, an effort that burns through the equivalent of about six pounds of flesh a day. Meg may have weighed as much as three times more, and would have presumably required proportional grub. Yet animals near the ocean floor have to get by on teensy scraps, preying on the scant species that live there or hoovering up biological detritus that sinks down from carcasses above.

This scarcity of food tends to make organisms evolve small, efficient forms, making many low-living sharks relatively sluggish and slight. A megalodon living far enough down to evade human detection might now look something like a sleeper shark—a long, cigar-shaped animal that's about as lively as it sounds—as opposed to a burly, toothy beast.

Yet even if Meg had assumed a slender and slow disguise, we'd probably have seen evidence of it by now. "Ocean giants that we do know about have global distributions," McClain says. Even if we rarely spy creatures like giant squids, which live in the more forgiving upper ranges of what we'd call the deep sea, they leave markers of their existence strewn around the world in the form of carcasses (and bites taken out of unlucky critters). We've yet to spot any such refuse, if it even exists.

But these realities can't extinguish the Meg's enduring myth (and summer movie franchises). "As a deep-sea explorer and as a scientist who spends a lot of time researching known ocean giants, I really want there to be some unknown one that is undiscovered, and to make that discovery," McClain says. Its mysterious nature—what we know of it comes largely from studying teeth—makes it enticing to imagine the Meg's pulled off the ultimate vanishing act and could, perhaps, reemerge at any moment. The key is where scientists decide to look. While paleontologists are almost certain megalodon doesn't swim in our modern seas, they might still find more details about the species in the depths of the fossil record—and its enduring secrets could break the surface when we least expect.

POPULAR SCIENCE

THE GOD MOD

BY SARAH SCOLES

ILLUSTRATIONS BY
TYLER SPANGLER

FALL 2020

PAGE 52

PSYCHEDELIC DRUGS CAN HELP EASE DEPRESSION, ANXIETY, AND ADDICTION. BUT WHY ARE THOSE RESULTS EVEN BETTER WHEN TRIP TAKERS HAVE A SPIRITUAL ENCOUNTER?

DOCTORS GAVE CLARK MARTIN A YEAR TO LIVE AFTER THEY FOUND HE HAD STAGE 4 KIDNEY CANCER IN 1990.

"I'M STILL HERE," HE SAYS NOW.

If the statement doesn't carry the triumphant tone one might expect of a person who has survived decades longer than medical science predicted, that's because the years of treatments, and the constant threat of death, dulled and depressed him for a long time. "It was exhausting," he says, "and it was no way to live."

In 2010, almost 20 years into his battle with cancer, Martin read about a strange research program. Participants wouldn't take a magic pill that might shrink their tumors in a novel way. No. They'd be getting drug-drugs: Brain scientists wanted to see how hallucinogens that alter thinking patterns and sensory perceptions might affect afflicted people's mental health. "I had always been interested in psychedelics but never had taken any," says Martin, a retired clinical psychologist. "I was terrified that I would mess up."

With someone else guiding him, though, the experience seemed less risky. Those someones—scientists in the psychiatry department of Johns Hopkins University—are part of the burgeoning field of psychedelic studies. Recently invigorated by a more permissive regulatory environment, the sector investigates if, how, and why reality-bending substances might help human brains. So far, research from all over the world suggests the drugs can break old mental patterns and help fight addiction, alleviate depression, shrink existential fears, and improve relationships.

Additionally, investigators have been surprised by another consistent finding: When people have spiritual experiences while tripping, they're even more likely to kick bad habits and be happier or more satisfied with their lives in the long term. The mysterious encounters take many forms. Sometimes people feel they're in the presence of God, or of a more nebulous entity like Ultimate Reality—a higher power that reveals the truth of the universe—or they just feel a novel connectedness to everything from now back to the big bang and beyond. Because of the link between the mystical and the medical, scientists like those at Johns Hopkins are probing why people have transcendent tendencies at all, how that might help our brains, and what it means for how we perceive the world.

Martin signed up for the trial and prepared for it in a series of counseling sessions with William Richards, a clinical psychologist at Johns Hopkins School of Medicine. On game day, Martin sat on a couch in a campus medical office that had been transformed into a calming living room,

with a statue of the Buddha, airy paintings, and yellow-light table lamps. Still, things did not begin smoothly. After he took his psilocybin—the hallucinatory compound in magic mushrooms—from a chalice, he reclined, put a mask over his eyes, and listened to classical music, as the researchers watched and guided his experience. But when the chemicals started to kick in, he panicked. “The things in the room no longer looked familiar,” Martin says, recalling what happened after he took off his mask. “Voices no longer made sense.” He sat straight up, wanting to run outside so he could look at something that would make reality snap back into place.

Seeing his distress, Richards put his arm around Martin’s shoulder. Richards didn’t speak or try to soothe Martin. He just acted as a steadying presence, tethering Martin to the known world, even as he began to enter a brand-new one.

The psilocybin soon worked its way fully into his physiology. And Martin found himself in a cathedral. Or rather a sort of gymnasium with stained-glass windows, which felt to him like a cathedral, because it seemed like a sanctuary.

“In my mind I said, ‘Well, if there’s ever going to be an opportunity to talk, this is it,’” he recalls.

And so he invited God to chat.

WHEN RICHARDS supervised Martin’s trip, he and Johns Hopkins colleague Roland Griffiths were on an uphill climb to establish their field’s significance in the treatment of mental illness and addiction. Their foundational work, including Richards’ 2015 book *Sacred Knowledge: Psychedelics and Religious Experiences*, has since inspired a new generation of scientists and led to the establishment in 2019 of the university’s Center for Psychedelic and Consciousness Research. The group employs about 30 people, from senior investigators to college kids, with Griffiths as director.

It’s a workplace that embraces rather than shuns the cliché parts of psychedelic culture, says research coordinator and former grad student Ian Geithner. On his office wall, for instance, hangs a tapestry of a mushroom and a big, all-seeing eye. A knee-high lava lamp lights the room. When Griffiths first saw the fixture, Geithner worried he’d think, “Unprofessional,” but he just pointed at it and said, “I haven’t seen one of those in ages!”

Griffiths and Richards’ work continues a line of official scientific inquiry that began in 1962 with a project called the Good Friday Experiment, conducted by doctor and Harvard Divinity student Walter Pahnke. He brought volunteers from his theology classes to a basement chapel where they would ingest either psilocybin or a placebo and hear the Good Friday service being piped in from above them. Afterward they wrote their accounts, and Pahnke scored their descriptions according to how well they fit the classical characteristics of a mystical experience. Developed by Princeton philosopher Walter Stace in 1960, that list of effects includes feeling unity with the universe, in touch with something holy, and as though the episode is hyperauthentic—more real than reality. About 40 percent of the Good Friday participants fit all the criteria "very well." A few years later, Richards, then working at the Maryland Psychiatric Research Center, co-authored a paper with Pahnke titled "Implications of LSD and Experimental Mysticism."

In the mid-1960s, though, new US regulations made producing and selling psychedelics illegal—whether for recreational or clinical use. Once these drugs became a synecdoche for the hippie counterculture, and some researchers (including ones at the CIA) did less-than-ethical work, the stigma stuck. Studying these substances depended on getting the go-ahead from the FDA and the Drug Enforcement Administration. The change essentially shut down most work like Pahnke's; the powers that be were tightfisted with both permission and research money for topics that might be seen as sketchy. Griffiths, who had been building up his street cred in psychopharmacology, instead rose to prominence studying people's relationships to alcohol, cigarettes, and sedatives. Only after he'd established himself as a legit substance-use investigator did he submit a safe research plan to the authorities.

After a decades-long dry spell, in 2000, Griffiths and Richards—who had since moved to Johns Hopkins—were the first of many to get a green light and funds to resume rigorous psilocybin studies. They began their project, funded by the National Institute of Drug Abuse, where Pahnke had left off: with mystical experiences and their effects on the mindsets of healthy volunteers. They wanted to know what would happen to the moods and psychologies of stable-brained people who ingested psilocybin, and what those changes had to do with any spiritual strangeness that might occur while they were under the influence. The men noted in their work that many cultures have centuries-old histories of using hallucinogens, a legacy and tradition researchers are now beginning to respect rather than dismiss for its nonmodern non-Westernness.

Their first endeavor was essentially a more rigorous, updated version of the Good Friday Experiment. In a double-blind study, the scientists gave 36 volunteers psilocybin in one session and a placebo during the next—or vice versa. When stimulated by the chemical, 61 percent of the subjects had a "complete mystical experience" that satisfied all of the criteria. One participant later told of a conversation with God—who had appeared as golden streams of light—assuring them that everything that exists is perfect, even if their limited corporeal self couldn't fully understand that. More than a year later, two-thirds of participants ranked their trip in the top five most spiritually significant moments in their lives.

Following this toe-dip back into mysticism, the Johns Hopkins group continued to investigate the links among psychedelics, spiritual episodes, and quality of life. In a follow-on from 2011, the majority of participants had complete mystical experiences, which produced "positive changes in attitudes, mood, and behavior" that stuck around long after the compounds were metabolized. In a study the same year that looked into personality traits, people who had had a mystical experience scored much higher for openness after the trip than they had before. The transformation was larger than adults—cemented in their ways—normally make over decades of natural maturation.

Next the scientists investigated whether psychedelics—which seemed to so alter psychology and perspective—might help curb addiction, as some decades-old and not-so-meticulous studies had suggested. In 2014 the team did a small trial with smokers. After two or three doses of psilocybin, along with cognitive behavioral therapy, 80 percent of the subjects quit for at least six months, the investigators found. Varenicline, the best smoking-cessation drug on the market at the time, had just around a 35 percent success rate, while cognitive behavioral therapy on its own typically led fewer than 30 percent of smokers to stop. Something else also stood out: If someone had a mystical experience while tripping, they were even more likely to succeed.

Regulation and stigma had also hampered early research into psychedelics' effects on anxiety and depression in cancer patients, so the Johns Hopkins team picked that back up too. Here their work, including the study in which Clark Martin participated, found the same spiritual uptick. The substances appeared to perhaps kick-start new patterns in the brain: less sad and scared ones, with shifted perspective and priorities.

As his own trip progressed, Martin—at last flying comfortably high—was ready to find out what the drugs might be able to do for him.

MARTIN WAITED FOR GOD TO TALK.

With the psilocybin coursing through his system, he stayed in his mental cathedral and waited for an answer from the God he'd reached out to.

And waited.

None came.

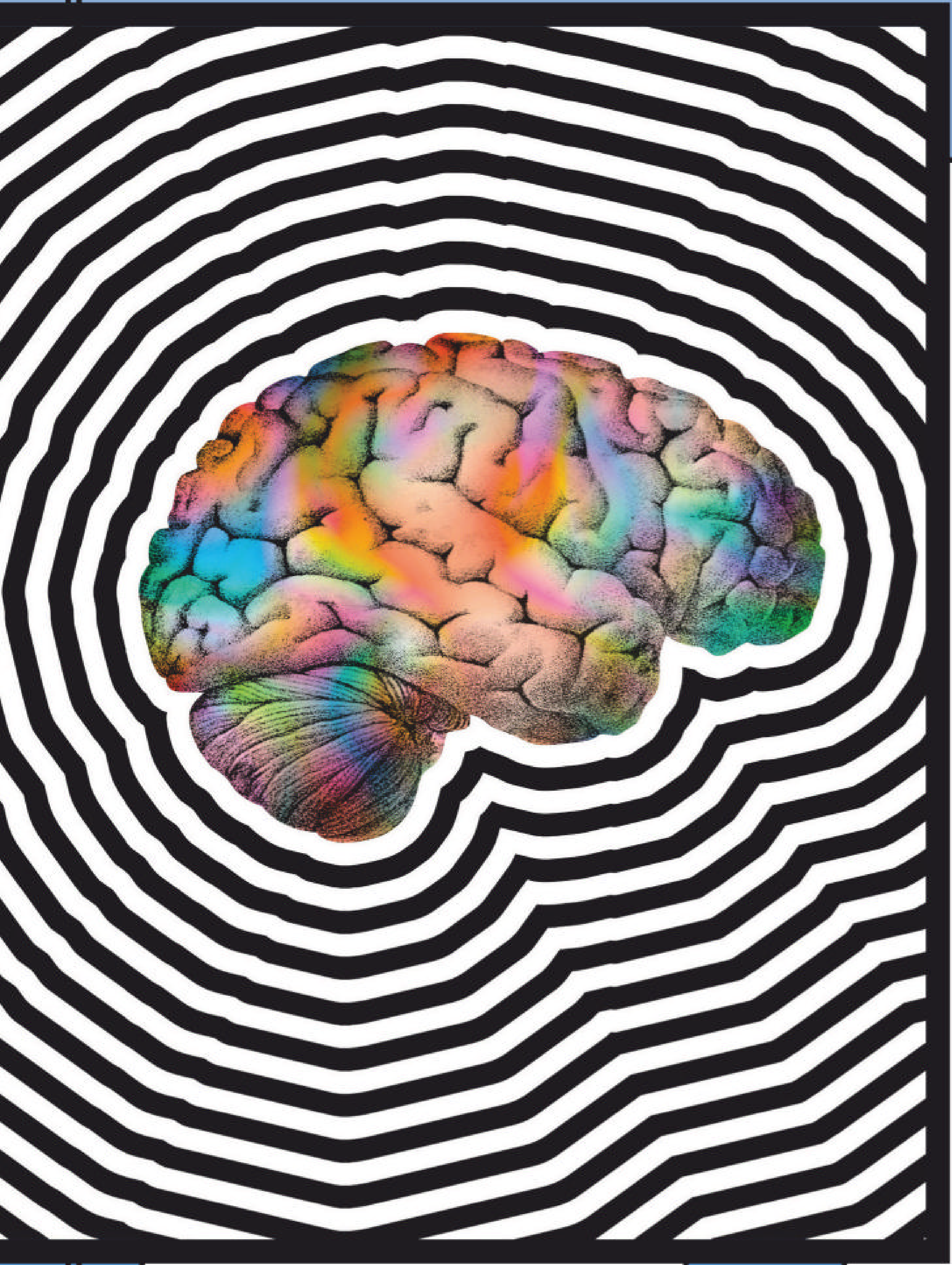
The silence did not disturb Martin, though. And soon another vision appeared. There he was: living on a bubble. Its surface was thick, yet fragile like a balloon, but it was the size of a planet. Other people were here too, living within different parts of its membrane.

It's tempting to view this as a metaphor, the way a dream interpreter might read into your nighttime interludes. But to Martin the images weren't abstractions. They weren't to be parsed. Meaning wasn't the point. "I didn't get hung up with them or try to make sense of them," he says of his Earth balloon, his gymnasium sanctuary, his absent God. He just experienced them.

That was new for Martin, who had navigated his life only with logic and rationality. This trip, though, was just about being alive and alert to every interaction, feeling whatever feelings he had, sensing whatever sensations arose. To use the hip lingo of mindfulness, he was Present.

After the session ended, so did his depression.

MARTIN DIDN'T HEAR from any deities, but plenty of other trippers have. Scientists want to understand how their perceptions compare to godly encounters sober people have, in terms



of quality, authenticity, and lasting effect. Alan Davis, an Ohio State professor of social work who collaborated on mental health and substance abuse studies as a postdoc in Griffiths' lab and is still affiliated with it, believes the mystical aspect of trips is a factor in their success. "It seems to be a big piece of the puzzle," he says.

To gather a wide variety of accounts—from a larger number of mind-altered and sober subjects than they could accommodate in the lab—Davis and his Johns Hopkins colleagues created an internet-based survey to find out about people's "God encounter experiences." The survey asked individuals about their most memorable rendezvous with a supreme figure, either when sober or when they had taken a psychedelic. More than 4,000 responded. They published the results in 2019.

The sober group was more likely than the other one to label the being God. The psychedelic users instead tended to call it Ultimate Reality. But both sets generally agreed that whatever they'd encountered was "conscious, benevolent, intelligent, sacred, eternal, and all-knowing." And the majority said the experience left them with more purpose and meaning, greater satisfaction with their lives, and a decreased fear of death.

Perhaps the most striking result, though, involved people from both groups who hadn't subscribed to the idea of a higher power to start with. After their hangout with an omniscient entity, more than two-thirds became believers. (If you've ever tried to change an atheist's mind, you know how big a feat that is.)

The shift means, essentially, that they thought the experience revealed something true about the world. As the paper put it, "The majority of both groups endorsed that that which was encountered existed, at least in part, in some other reality and that it continued to exist after the encounter."

One participant, a data architect in his 40s who wished to remain anonymous because his substance use occurred outside a clinical setting, has had plenty of mystical encounters, but he views these chemical creations as internal. "Psychedelics allow you to explore your own mind," he says. For instance, when he met Jesus Christ while under the influence of ayahuasca, he believed he was simply meeting "the construct of Christ that exists in my own mind."

Whether or not such occurrences reveal something about the actual nature of the universe doesn't necessarily change the clinical outcomes. "If someone did have a God-encounter experience," Davis says, "and because of this they say, 'I now know that God exists,' people get rubbed the wrong way: 'You can't possibly know that. You can't prove that to be true.' As a scientist, I agree with that."

However, if it's not real, he adds, "That doesn't make the experience any less valuable. The clinician part of me is like, 'Does it matter if it's true?'"

WHETHER THE MYSTICAL experiences are real or imagined, or both, the positive changes they produce in people stick around, and scientists are closing in on some potential chemical reasons why psychedelics so often leave folks feeling misty-eyed and spiritual.

Johns Hopkins' Roland Griffiths and colleague Frederick Barrett, a cognitive neuroscientist, laid out the basics in a 2017 paper called "Classic Hallucinogens and Mystical Experiences: Phenomenology and Neural Correlates." To start, certain psychedelics stick to serotonin receptors called 5-HT2A in the central nervous system, producing classic trippy effects in ways neuroscientists don't totally understand yet. But the substances seem to most affect a framework in the brain called the default mode network, which typically lights up when you're pointing your attention inside yourself and not toward the outside world—like when you're daydreaming. When you pop or sip or chomp on a hallucinogen, this grid calms down, and its connections and oscillations change. Since in its sober state, it's all about self-contemplation, Griffiths and Barrett suspect that disrupting it results in the opposite: the "dissolution of the self," or the loss of your sense of being a lone individual. That could also explain the feeling of connectedness to everything outside who you are.

Changes in this network also remove your sense of space and time. Voila: mystical experience.

Is that really...it?

Not quite, according to Bar-Ilan University's Ido Hartogsohn, a scholar of science, technology, and society. He postulates that psychedelic encounters with the seemingly divine feel so significant—so real—because the drugs also enhance the meaning people impose on experiences. Consider that if you had a simple nighttime dream in which you met God, you'd be more likely to wake up, shake your head, and tell the story as a funny anecdote than you'd be to ditch your atheism. Hartogsohn's work is more philosophical than neurological, but the people wielding the fMRI machines could devise ways to investigate his ideas.

And perhaps they will. Because no one really knows for sure yet why these drugs make people mystical, what that mysticality really means, or exactly why any of it changes people's personalities for the better, boosts them out of mood disorders, or rids them of addictions. Those questions merit answers. The science's consistent results have helped erode the stigma surrounding hallucinogens and taken them beyond the province of hippies, military experiments, and fringe academics. After approvals and research funding resumed in the late 1990s, that work largely happened through drug-focused nonprofit organizations like the Multidisciplinary Association for Psychedelic Studies and the Heffter Research Institute. Now universities have membership cards too. In April 2019, Imperial College London spun up the Centre for Psychedelic Research. Johns Hopkins opened its center the same year. Clinical trials are ongoing or have been approved at the University of Chicago, Yale, New York University, the University of Arizona, and the University of California, San Francisco, among others.

Whatever you make of them, psychedelic treatments hold promise that keeps pushing the research forward. Davis thinks often of a young woman in a Johns Hopkins study who had struggled for a decade with severe depression and social anxiety. She thought about suicide often. But after her treatment with psilocybin, things changed. For example, Davis says, "The look in her eye that she had gone a whole week without thinking of ending her life. It doesn't get better than seeing hope in somebody."

Davis believes psychedelics do something deeper than traditional pharmaceuticals or therapies. "Whether that's because of the mystical experiences or the insight, something is happening at a level that is not just about reducing symptoms," he says.

That's what ensued for Clark Martin. Instead of focusing on cosmic connectedness, he thought about how to forge better interpersonal links with people here on the ground—especially his daughter and his father, who was struggling with Alzheimer's. Martin recalls his intuitive experience of his surroundings, both illusory and physical, and how much the mere presence of psychologist Richards meant to him. He wanted to find a way to be there for others.

"It wasn't about being smarter or reading more stuff," he says. "It was having a visceral experience of the alternative"—living a moment emotionally, listening, and just *being there*—"and understanding it was possible. I don't think any amount of smarts and education would do the same."

No, it took someone placing a magic-mushroom compound in a chalice—for science—and passing it to a man who'd been almost-dying for far too long.

EVIDENCE
TO BE OPENED BY AUTHORIZED PERSONNEL ONLY
EVIDENC
TO BE OPENED BY AUTHORIZED PER

inside the ultimate bee sting

BY
ANDREW ZALESKI

PHOTOGRAPHS BY
THE VOORHES

one man has a plan to get bandits to buzz off

The bee thieves come at night, swooping in and bugging out quicker than the wings of the insects they steal. And they always leave tracks.

Ray Olivarez knew this much, but he still expected a routine visit when he drove to his apiary in California's Central Valley one brisk midwinter afternoon in 2016. As he parked, though, an uneasiness fell over him. His hives hadn't been visible when he'd crested the hill. As he slowly marched toward the entrance, his face fell. The lock on the gate? Cut. His instincts kicked in, and he looked down, seeing squelched mud imprinted with ribbed tread marks.

A few days earlier, this yard had been home to 64 white wooden boxes of bees almost ready to make the trip to a local almond farm, where they would pollinate the trees. Now all he saw were the rectangular impressions they'd left in the grass. Like hundreds of other honey farmers every year, Olivarez was the victim of one of the most fiendish agricultural crimes in America: hive theft.

Central California's temperate climate provides ideal conditions for the interdependent activities of raising bees and growing almonds. Mild winter rains spur the nuts to grow, while dry summers ensure they don't fall victim to fungal infections before harvest. The state produces 80 percent of the world's crop, with the bulk of its 1.3 million acres of trees clustered throughout a few particularly fertile counties. From February through mid-March, their buds burst into petals of pink and white—an irresistible treat to honeybees. Farmers rent *Apis mellifera* by the boxful to pollinate their orchards (it's easier, and less time-consuming, than tending bees themselves); hitting all 250,000 farms requires the labor of some 500,000 hives native to California, as well as another 1.5 million trucked in from as far east as Florida. That's 31 billion buzzing critters in total.

The big migration usually begins in January, with apiarists hauling hive-laden pallets to orchards on flatbed trucks and hoisting them off with forklifts. The rule, generally, is two boxes per acre of almonds. A crate of pollinators that would have cost just $11 to rent in the 1970s is now more than 10 times as valuable. A seasoned, second-generation bee wrangler like Olivarez, with 18,000 hives of strong insects, can command anywhere from $180 to $220 for each.

But within weeks of arrival, the first signs of trouble emerge: a box lifted from some rural orchard, a pallet gone missing overnight. As the value of the crates has risen, so too has a new class of criminals hell-bent on stealing honeybees.

That's the situation Olivarez found himself in. He'd parked his colonies on a farm three hours north of San Francisco in January. When he checked in days later and found tire tracks, he figured foul play was afoot.

"Bees are an easy target to grab and load in the back of a pickup," Olivarez says. "But the lucky thing is that they were stolen in Butte County, which is Rowdy's jurisdiction." That's Rowdy Jay Freeman, bee-thief gumshoe extraordinaire.

A 15-year veteran officer as well as vice president of the state's rural crime prevention task force, Freeman polices the county as a deputy sheriff. But over the past decade, he's come to be the main liaison between law enforcement and the victims of hive heists. It's a role he grew into, first thanks to

insight he gained keeping his own hives, and more recently by embracing the latest in security technology to thwart thieves.

"I receive more attention from bee thefts than any homicide case I've ever worked," says Freeman, who tends to be laconic, but is nevertheless easy to distinguish: Look for the shiny shaved head sitting atop a thin frame in a brown sheriff's uniform.

FROM JANUARY TO MARCH, Freeman drives the roads along Central Valley's almond orchards, keeping a watchful eye and fielding tips. Bee theft first hit his desk in 2012, while he worked the felony investigations unit inside the county sheriff's department. When the hive owner called Freeman to the scene, he blamed the crime on the hefty sums keepers secure from farmers to pollinate their almond crops. "At the time it didn't make a whole lot of sense to me," Freeman recalls. "I didn't understand the business."

Back at the office, he gave himself a crash course on how the pollinators contribute to almond farming. Every hive contains one queen and tens of thousands of drones and workers. The drones are male; they mate with the queen, then immediately die. The workers are female and live for as little as four weeks, feeding the queen, caring for the drones, collecting nectar, pollinating, and producing honey.

These days, just as the market for their services is surging, the creatures require more care than ever before. "You can't just put bees out there like in the 1970s and go take the honey out in two

Sheriff Rowdy Jay Freeman now has a personal passion for bees.

months," says Eric Mussen, an emeritus apiculturist at the University of California, Davis. "If you're away for two months these days, you'll probably have half your bees gone."

That's because in 1987 the pernicious varroa mite started laying siege to American honeybees. The parasite lays its eggs on pupae as they're growing inside hives, sapping nutrients and carrying a disease that causes adult bees to emerge with deformed, unusable wings. Varroa mites also spread viruses that help trigger colony collapse, a puzzling phenomenon that causes the inhabitants to buzz away, never to return.

As mites proliferated, apiarists who had once lost around 5 percent of their colonies each year saw the number soar to as much as 50 percent. Moreover, the great irony of California's robust almond industry is that it has, along with other agricultural pursuits, gradually crowded out natural foraging land for bees. Despite their diminutive size, the insects are capable of flying as far as five miles to collect nectar. But with a dearth of wildflowers, local breeders must now supplement nature's food with pricey sugar solutions.

While Freeman had grown up in a small agricultural community, the nuances of the honeybee industry were new to him—and he was fascinated. "I couldn't believe how much there was to it and how intelligent these insects are," Freeman says. "It sucked me in." After his first theft investigation, he became so absorbed in the intricacies of beekeeping that he ended up buying six hives of his own the following year. Caring for a humming brood has made him appreciate just how precious a healthy colony is.

He also realized no one kept track of these thefts, so he began doing so himself. In 2013, according to his tally, just 128 boxes vanished. Soon he started noticing a pattern. Many thieves use the same flatbed trucks and forklifts to steal hives that apiaries use to transport them—leading to the inescapable conclusion that the criminals looking to make a quick buck are often insiders.

"Hive theft is almost like the perfect crime, because it's beekeepers stealing from other beekeepers in a lot of instances," Freeman says. "To a lot of people, it just looks like maybe the thief is taking care of their own hives." That makes it almost impossible to spot a crook in the act. Many capers are grab-and-go schemes that unfold quickly, aided by pollinating logistics. The boxes often sit scattered on the periphery of a farm, near the sides of roads and along driveways. That simplifies the drop-off and pickup process for both apiarist and farmer—and for highway hive robbery too. "Thieves go in early or late at night and can load several hundreds in 20 minutes, hit the road, and be gone," says Freeman.

In his first four years policing insect crimes, Freeman didn't catch one thief—but he did build a network of trust. In 2016, a year when bandits made off with more than 1,500 hives, a fellow apiculturist called the cops after spotting Olivarez's branding on boxes that had appeared suddenly four counties south of his usual stomping grounds. Two weeks later, Freeman cuffed 32-year-old Jacob Spath.

Spath was a small-time beekeeper, who—in a twist seemingly tailor-made to showcase the insular nature of the industry—had learned the ins and outs from Olivarez's parents. He'd even managed to prepare 76 hives for pollination the year before. But in 2016, the farmer with whom he contracted required 170. That's when Spath started snooping. He could see Olivarez wasn't careless. In addition to printing his surname on all his hives, he distributed the boxes throughout the holding yard instead of leaving them by the road. He'd even gone as far as installing protective gates on his own dime. But Spath had an advantage just by virtue of the bee yard's location: a secluded area near a municipal airport. Under cover of darkness, Spath cut the lock on the gate and used a forklift borrowed from Olivarez's parents to load their son's 64 hive boxes, four to a pallet, onto a flatbed truck. Spath then drove four hours south.

It may have been a lucky tip that led Freeman to the arrest, but it was his ability to connect with the tight-knit community—and his passion for investigating the heists—that put him in a position to receive it.

"He's taken it to another level for us," Olivarez says. "He's somebody that we can count on to help us with connections in other counties, with sheriff's departments and police enforcement. And he's been a spokesperson for us."

Butte County officials charged Spath with grand theft of an animal, a first for bee thieves in California. He pleaded guilty four months after he stole Olivarez's boxes, and the court sentenced him to 90 days in jail.

Whether his time behind bars had a wider effect is doubtful. After peaking above 1,000 in 2016 and 2017, thefts dipped to just 300 in 2018, but rose again to 542 in 2019. Buzz Landon, vice president of the California State Beekeepers Association, worries that robberies will put folks out of business.

"This is wrecking people's livelihoods," says Landon, who mentored Freeman when the lawman got into bees. Most keepers spend about $300 per hive to keep them healthy throughout the year. Money they make in rental fees generally covers those costs; in the summer, honey

COURTESY OF THE CALIFORNIA FARM BUREAU FEDERATION

production helps turn a profit.

Thefts disrupt the entire process. Fewer hives available for rent means less money, which means less to invest back into care—which, ultimately, means fewer bees. Freeman's industry contacts made it clear that 90 days in jail wouldn't be much of a deterrent. The chances of capture were too slim, the potential payoffs too high. He decided it was time to focus his expertise on catching crooks in the act.

ON AN OVERCAST SATURDAY IN late April 2020, Freeman dons a different type of uniform: a large white suit, almost like a painter's outfit, and long blue gloves. An oversize netted hood shrouds his large-bridged nose and strong, cleft chin. In front of him are 96 white wooden boxes. Tiny honeybees swarm all around him.

Today he owns 500 hives, and he can tell you off the top of his head how much trouble he'd be in if someone stole them. He spends $23,000 a year alone on sugar solution, which he adds to his hives' diet periodically to ensure they're healthy enough to make honey come summer. He's no casual keeper these days, and his personal investment in the insects helps drive his mission to track down thieves.

"I can help with both sides of the case: the law enforcement standpoint and the beekeeper's standpoint," says Freeman.

Freeman routinely advises peers on how to protect their colonies. Most in the industry know enough to brand equipment with their name, phone number, or personalized codes. Some stick GPS trackers on pallets, betting that robbers will forklift the whole lot instead of picking up individual boxes. Some even pool their money and hire private security guards to conduct nightly orchard patrols.

Increasingly, Freeman promotes technological approaches. He's supported outfitting pallets with microchips similar to the type owners use to claim runaway pets. And several years ago, Wildlife Protection Solutions, a nonprofit that works to prevent big-game poaching, contacted him about installing cameras in orchards during pollination season. The group provided him with one to test out, and now he's looking to make them widely available.

"The neat thing about these is they're hooked up to the cloud," says Freeman. "If the thieves decide to break the camera or steal it, well, those pictures are stored, so you have them no matter what."

All of this pales in comparison to Freeman's latest plan. In 2019 he started working with SmartWater CSI, a Florida-based company that produces a proprietary traceable liquid. Even after washing, the substances can remain on clothing and skin for weeks, visible only under UV light. They can also shine through layers of paint—so bee thieves can't easily cover up an identifying dab on the outside of a hive box.

Whether this level of trickery will help Freeman identify bee snatchers will be revealed during the next few pollinating seasons, but an early trial convinced him that the stuff works. In 2020, thanks to SmartWater, his department finally booked two culprits who had repeatedly stolen GPS-equipped farming hardware. "The thieves had the solution all over their hands and all over the stolen equipment," he says. "It was pretty cool to see it all come together and work as it's intended."

> "Hive theft is almost like the perfect crime…it's beekeepers stealing from other beekeepers."
>
> —*ROWDY JAY FREEMAN*

Freeman has set up a pilot program with the sheriff's department to distribute the technology ahead of the 2021 pollination season. At least one of his buddies is already using it: Buzz Landon, who rents out about 3,500 hives annually.

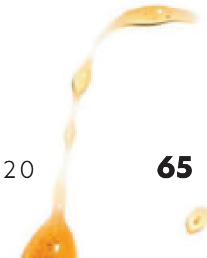
Thwarting treachery isn't cheap. GPS trackers cost around $200 a pop, plus an annual subscription service. At about $3 each, microchips are relatively thrifty, but equipping hundreds or thousands of hives quickly turns impractical. Outfitting Olivarez's fleet of colonies would run more than $50,000. Freeman says marking boxes with SmartWater adds up to a few hundred bucks.

"I've been trying to express to beekeepers that you really do need to do this stuff. It's an expense, but it costs a lot more to lose a bunch of hives," he says.

Walking among his bees in the early afternoon, he remarks that in seven years, none of his own boxes have ever been stolen. He's one of the lucky ones. Thieves hauled away 639 hives over the 2020 pollination season, an increase over the previous year.

"It really does piss you off," he says. "A lot of these beekeepers are my friends." His word means a lot to them, since, after all, he's one of them now. That should help as he tries to get others to adopt antitheft tech—the final piece, he hopes, in truly stemming hive heists.

Come January, Freeman will be out patrolling in the orchards once again. For now, there are bees to tend to. Soon they will start producing honey, collecting nectar from nearby plants and holding it in a secondary stomach in order to get it back to the hive. But this day marks a different occasion: It's feeding day on this grassy field in the Central Valley. A flatbed truck is parked nearby, with a giant tank full of sugar syrup sitting on top. As he opens his hive boxes, gangs of eager honeybees swarm the tiny yellow feeding troughs oozing with sweet liquid. Standing over them, Freeman cracks a proud smile.



WHERE THE SUN DON'T SHINE

DANK.
TOMB-LIKE.
UNCIVILIZED.
CAVES GET A
BAD RAP, BUT
SCIENTISTS
AND EXPLORERS
ARE PLUNGING
DEEPER TO
LEARN THE
TRUE NATURE
OF THESE
INKY, ROCKY
CAVERNS.

PHOTOGRAPHS BY
ROBBIE SHONE

BY **PURBITA SAHA**

CAVES HIDE SOME OF THE EARTH'S BEST-GUARDED SECRETS.

Formed by millennia of rain trickling through bedrock and ice, these recesses act as time capsules for anthropologists, biologists, and climatologists, who search them for precious remnants of life predating even the dinosaurs. Today, caving also attracts nyctophiles seeking calm darkness and self-trained cartographers looking to draw a more complete picture of the planet's past and present.

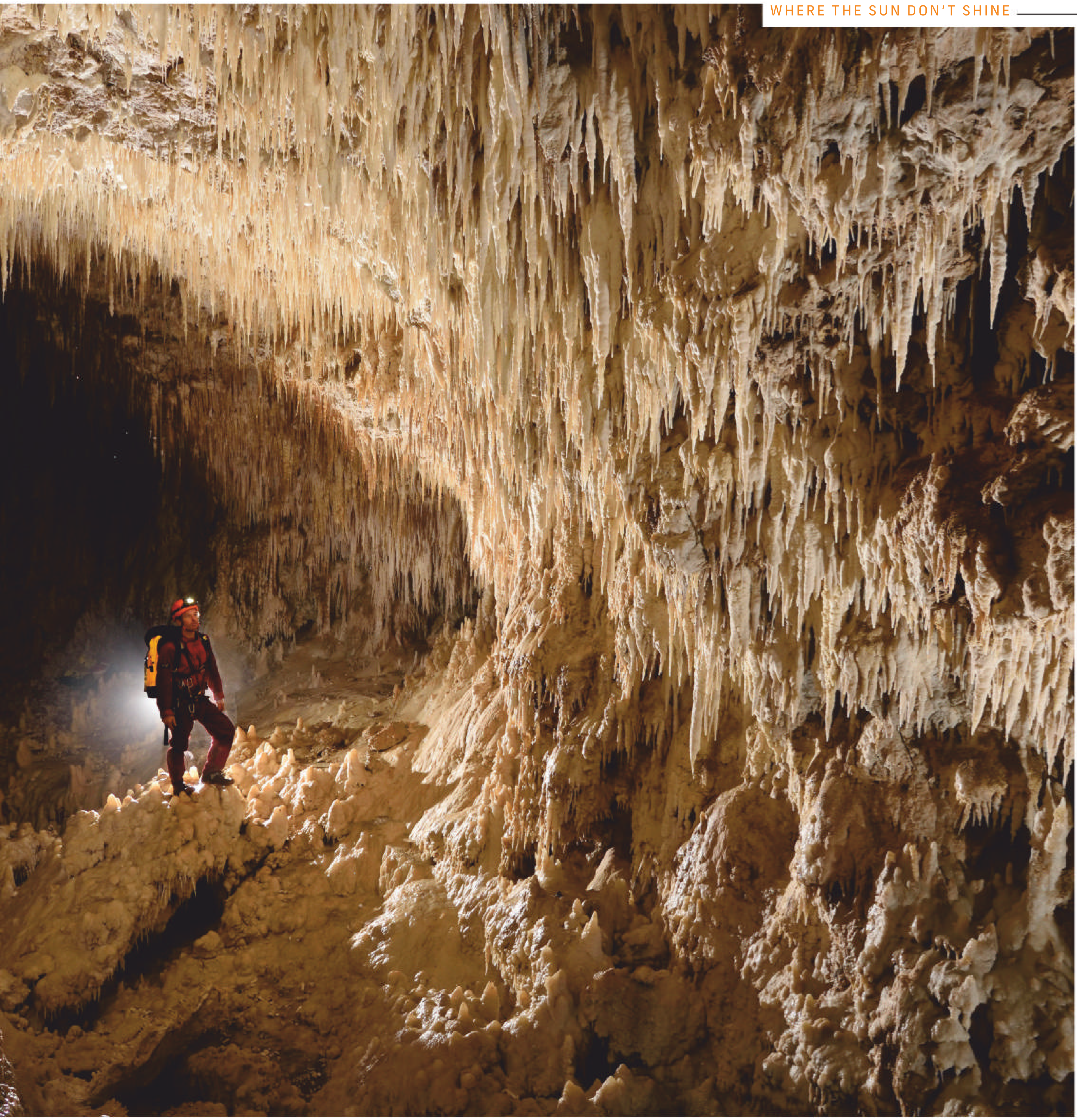
Austria-based photographer Robbie Shone dropped into his first "cold, dirty hole in the ground" with an experienced friend while studying landscape art 20 years ago. Since then, he's descended hundreds of times with cameras and flashbulbs strapped to his back, all to document the surprising diversity of subterranean structures. With each image, he aims to depict caves as places of "safety and beauty," instead of the stuff of nightmares.

STONE FALL

(PREVIOUS)

CHINA

Shone spent around three weeks with an American expedition in the Tongzi cave system in eastern China. After dozens of miles, the limestone maze gave way to a 65-foot-tall gallery, where heavy rocks have dropped from the ceiling to form what the photographer describes as a "bed of Legos." Standing inside the space, it's difficult to comprehend its volume: Even the most powerful headlamps, Shone says, can't penetrate the pitch-black roof, which human eyes have likely never seen.



ACID DRIP (ABOVE)

PAPUA NEW GUINEA

Lush forests and heavy rainfall in Papua New Guinea make the country's underground expanses look like Swarovski showrooms. During monsoons, acidic water drips down through the limestone, forming calcite-crystal stalactites on the ceiling. Gina Moseley, a paleoclimatologist at the University of Innsbruck in Austria (and Shone's fiancée), explains that stalagmites on the ground store clues about the region's climate and vegetation that could date back half a million years.

MICROBE PROBE

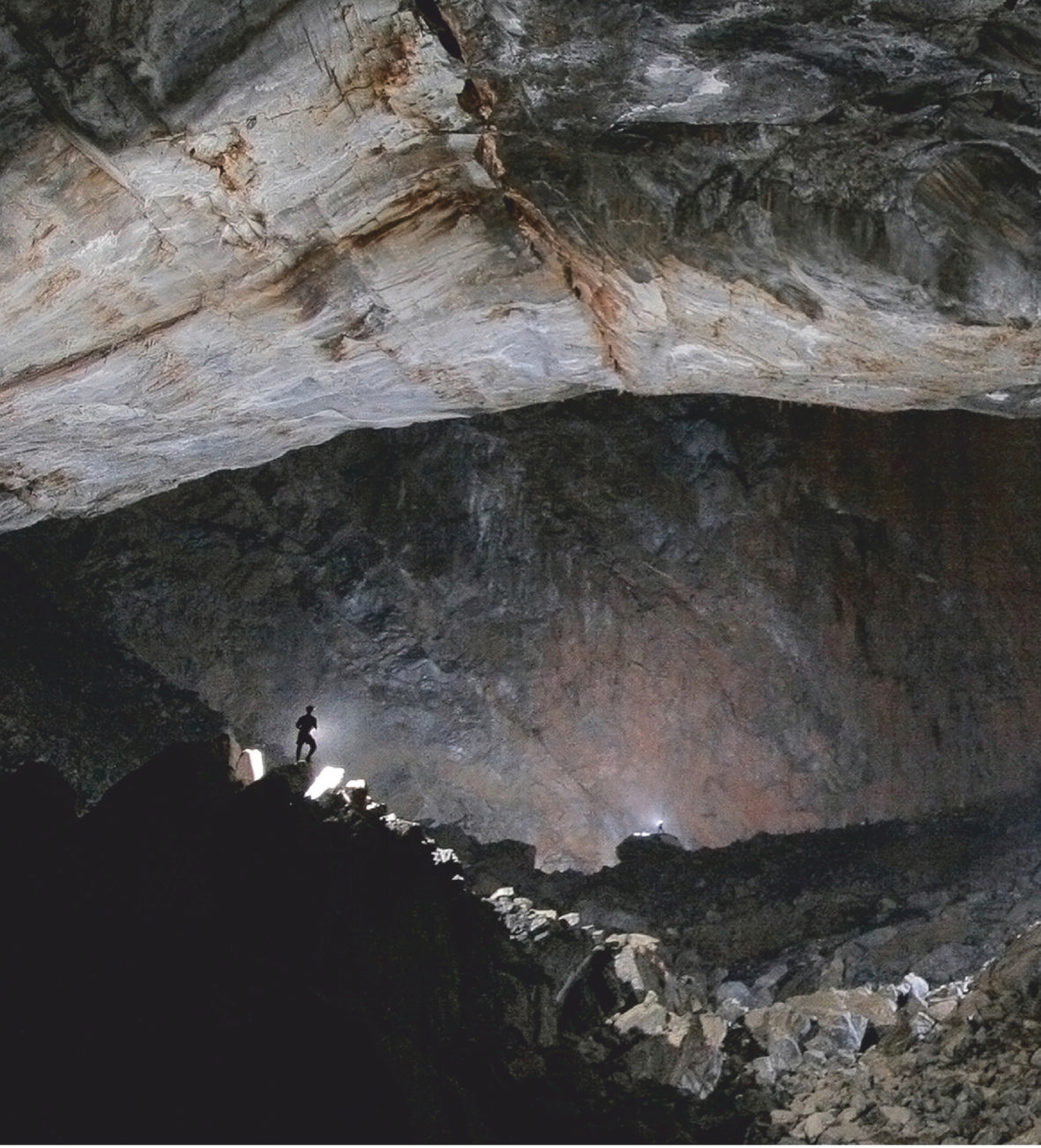
VENEZUELA

This 2016 self-portrait depicts Shone posing in the back of a long quartzite cave under Venezuela's tabletop mountains, known by locals as *tepuis*, or "houses of gods." He'd tagged along with an Italian team of microbiologists who were sampling bacteria from the underwater rocks and lakes to, among other things, study topics such as antibiotic resistance. The damp recesses under the tepuis house a rare network of organisms, known as stromatolites.

CARVING STONE

FRANCE

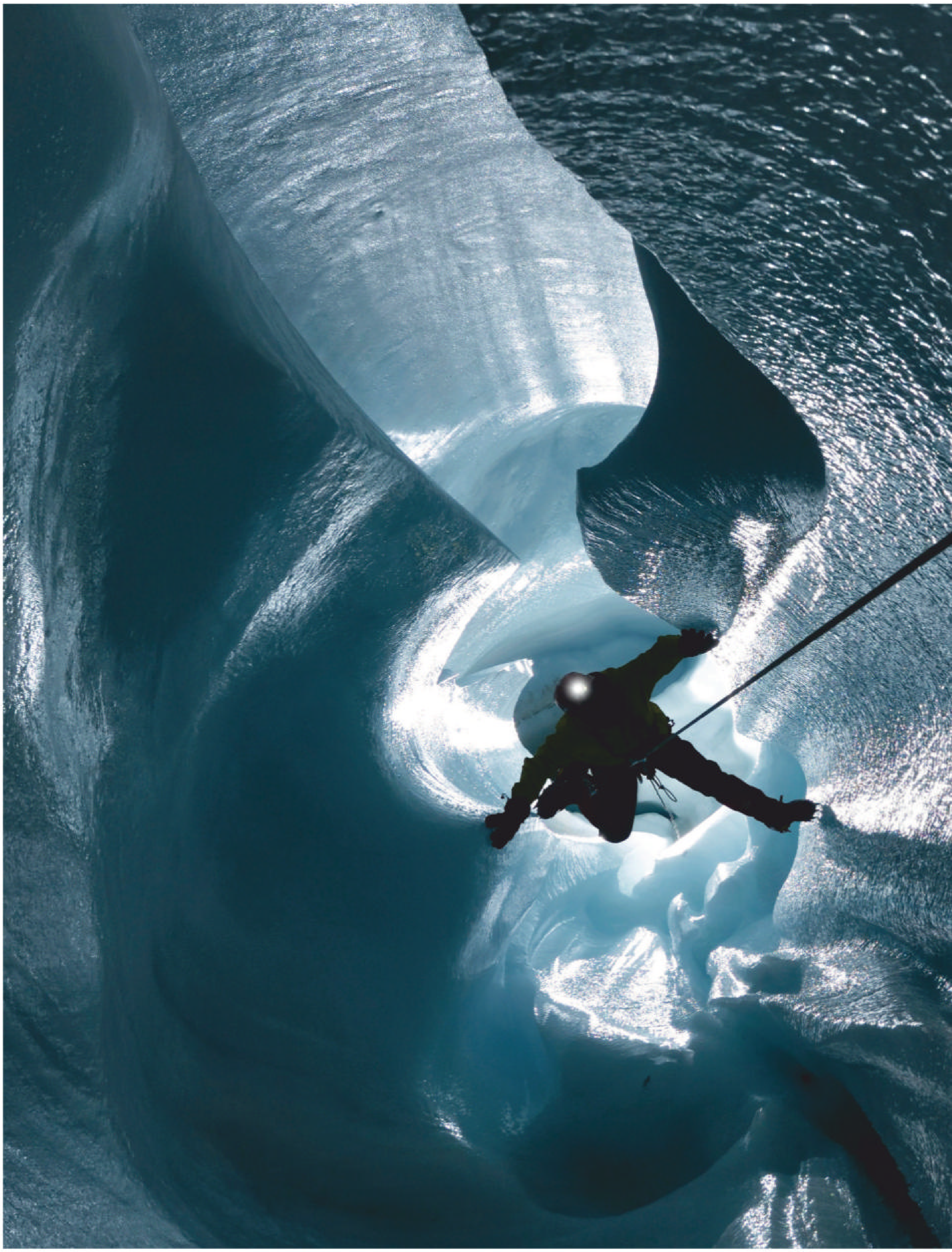
The Gouffre Berger system in France descends to a nadir that sits 3,500 feet below sea level, about the height of three and a half Eiffel Towers. To get there, cavers spend at least 15 minutes paddling through a freezing, 10-foot-deep river. As Shone's fellow explorer illustrates here, a waterproof camera bag can serve as a flotation device. In heavier rains, the porous limestone in the well-documented system allows the eroding water to surge to the roof, continuing to slowly carve the rock in the process.



MEETING ROOM

BORNEO

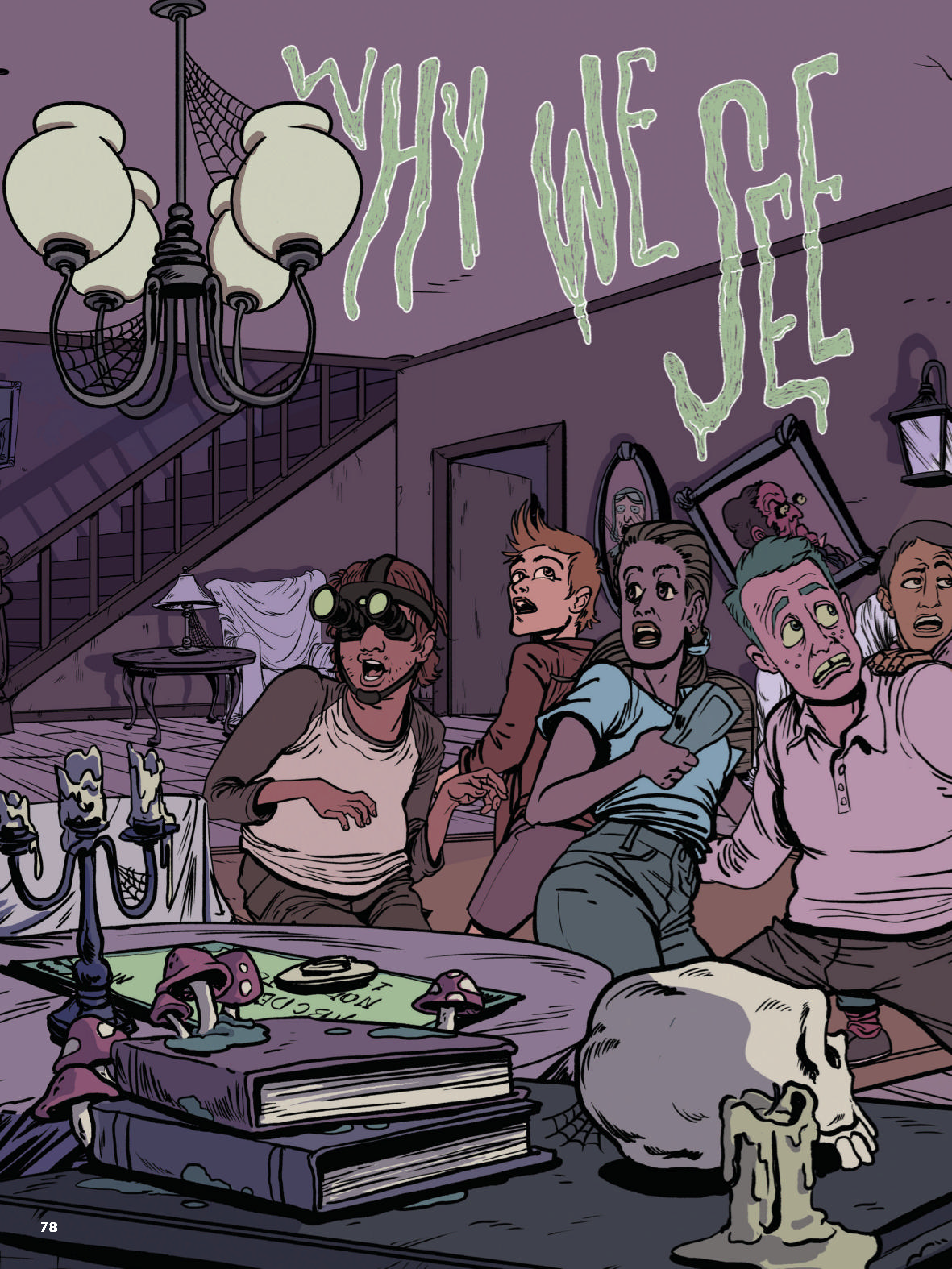
Shone's companions take in the view in this "fire room," one of the world's largest chambers, during a trek in Borneo. The dramatic rift marks where three bodies of water once converged over thousands of years. Gray limestone walls smeared by red, iron-oxidized patches make for a multicolored backdrop. The journey here has its harrowing moments: Snakes, scorpions, and ginormous spiders chased the entourage as they embarked on their day-long hike from the system entrance.



SLIPPERY SLOPE

SWITZERLAND

Glacial caves fill with water during the day and then freeze solid overnight, giving climatologists a limited window of time to drop in and study their eccentric, constantly shifting features. In 2018, Shone and a pack of Welsh researchers had to wriggle down the silky, narrow walls of this chute in Switzerland to measure how quickly the ice was shifting due to the region's rapidly changing climate. "I guarantee this geology is no longer there," Shone says.


WHY WE SEE

GHOSTS

A

ARE GHOULS REAL? That depends. Current science can't prove that there are spirits walking through walls or screaming below floorboards. Our spooky sightings, however, have certainly felt real. Humans have been spotting specters for as long as we've been around, and to some degree we can explain why. These seven mental and physical factors can account for almost any creepy occurrence—including some famous ones ripe for debunking—and help to make sense of our perpetual urge to sleep with the night light on.

BY JAKE BITTLE

ILLUSTRATIONS BY MC WOLFMAN

YOU WANT TO BELIEVE

I KNOW THAT GHOSTS have wandered on earth." So says the tormented hero Heathcliff in *Wuthering Heights*, and he's not alone: Even for the most grounded among us, there's something irresistible about haunted houses and vengeful spirits. Sometimes, hoping for a spectral sighting (or, like Heathcliff, dreading one) is enough for us to conjure a wraith.

Thanks to campfire tales and multimillion-dollar horror flicks, spooky notions can infiltrate our subconscious even without any real-life supernatural encounters. Nearly half of Americans think ghosts are real, according to market research company YouGov (bloodsucking vampires scored a measly 13 percent). That preconception primes our minds to run wild whenever we hear a creaky floorboard or feel a sudden chill.

"Believers are a lot more likely to report anomalous sensations, and they're also more likely to conclude that those sensations indicate a ghostly presence," says Chris French, head of the Anomalistic Psychology Research Unit at Goldsmiths, University of London as well as a self-described "wet blanket" skeptic.

We have such a tendency because the human mind is highly suggestible, French says. We've evolved to take cues from the outside world to escape threats like an animal chasing us, so a well-placed hint can make us see things that aren't there. In the 1990s, psychologists at the University of Illinois at Springfield gave the same tour of the century-old and long-closed Lincoln Square Theater to two groups of people, telling only one cohort that they were investigating a haunting; sure enough, the visitors who were informed of the excursion's specifics were far more likely to report intense emotions and strange occurrences. This mental quirk is so powerful that it can deceive us even in real time: In another study, conducted by Goldsmiths' French, participants were much more likely to report witnessing a key bending of its own accord if someone standing next to them mentioned they had seen the eerie incident happen too.

Our preconceptions can also cause us to find supernatural evidence in garbled noise or blurred images. French says this phenomenon, called pareidolia, can explain many supposed recordings of phantom voices. If a ghost hunter or psychic instructs you to listen for a certain phrase, then your brain (which loves identifying patterns) tries as hard as it can to create those exact words from various bits of random sound.

YOU'D RATHER NOT RISK *IT*

IT'S EASY TO DISREGARD the notion of paranormal activity in broad daylight, but everything changes when you head into a dark basement. Unfamiliar and threatening environments kick our survival instincts up a notch.

"If you're walking in the woods and you see movement, you can make two errors," says Michiel van Elk, a professor of social psychology at Leiden University. "You can either think it's nothing, and it could be a potential predator, or you can think there's a predator, and there's nothing." Psychologists suspect humans evolved a cognitive bias toward the latter mistake for good reason: Our ancestors had to keep a constant lookout for stealthy hazards like leopards and snakes, and folks with a "better safe than sorry" attitude were more likely to survive and reproduce. But, van Elk says, this propensity can cause us to sense the presence of another even when we're alone. That's why a snapping twig can activate the fight-or-flight reflexes that make us scream.

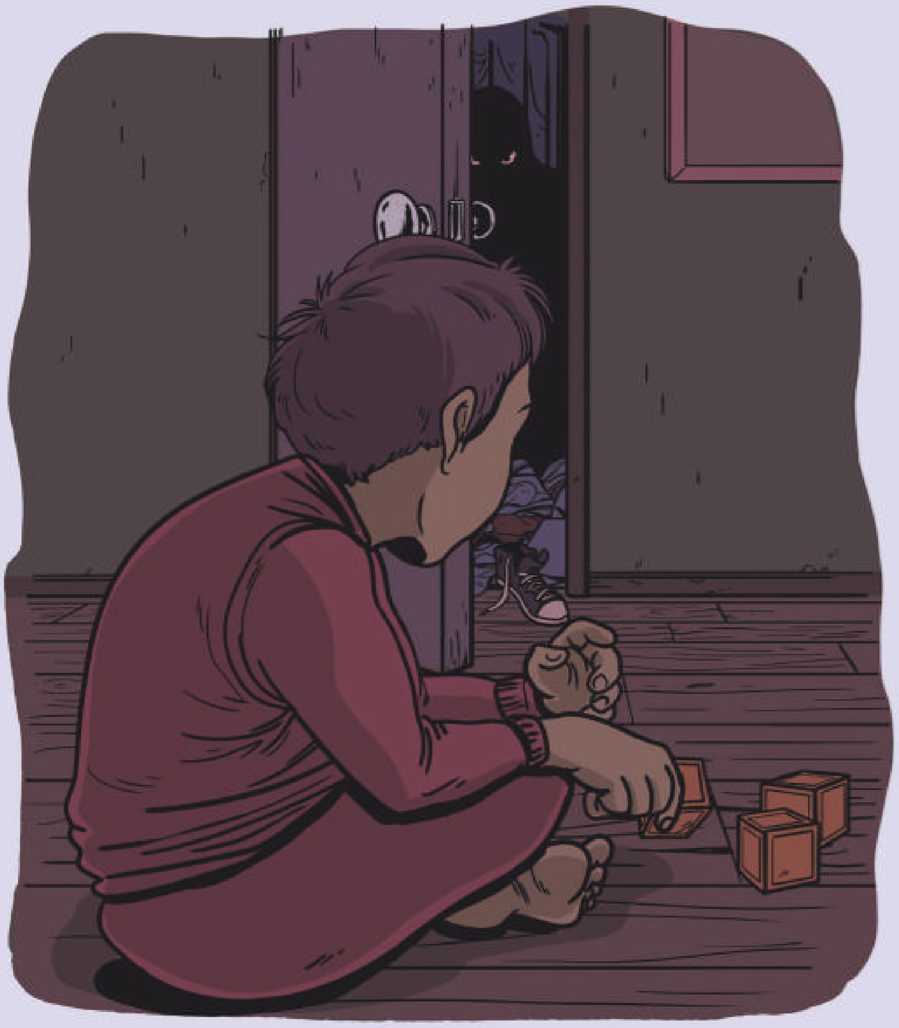
Ghost tours capitalize on this hereditary paranoia by forcing the mind to wrestle with ambiguity. A good haunted mansion doesn't shove a spirit right in your face, but encourages you to wonder if you might have just seen one out of the corner of your eye. The uncertainty itself drives up the fear factor. Even quirks of architecture can trigger this primitive terror: In 1975, British geographer Jay Appleton found that, when it comes to our habitats, humans tend to think of places as safe when they offer two things: prospect (a clear view of the outside world) and refuge (the opportunity to hide from danger). A poorly lit old house gives us neither of those two accommodations, blocking our ability to see what's around the corner and providing plenty of shadows in which malicious entities could lurk.

● historic haunts

OCCULT CLUBS

Victorian Britain was obsessed with hauntings, perhaps because spooky Gothic novels offered up cheap entertainment. In the mid-1800s, a number of high-minded fanatics founded not-so-secret circles devoted to the paranormal. The still-active Society for Psychical Research took a particularly scientific approach: Its main members included physicists, mathematicians, and journalists. In the 1880s and 1890s, the club published papers debunking claimed mediums and telepathic seers. The group's strict standards led Sherlock Holmes author Sir Arthur Conan Doyle to resign in 1930, grouching that his peers were wrong to disbelieve reports of levitation in an Italian mansion.

Not every institution was quite so stringent. Conan Doyle also happened to be a card-carrying member of the Ghost Club, a short-lived band founded by Charles Dickens to investigate séances and reports of people in hypnotic trances. After Dickens died, other associates abandoned any guise of skepticism and turned the group into a haven for "true believers." They held elaborate rituals and activities like psychography, in which members, while in a "semi-conscious" state, held pen to paper and scribbled messages that came to them.



YOU NEED A LITTLE COMPANY

THE APPARITIONS IN MOVIES LIKE *THE GRUDGE* and *The Amityville Horror* will stop at nothing to chase down their human victims, but ghosts aren't innately terrifying. Research suggests that the brain may summon spirits as a means of coping with trauma, especially the pain of losing a loved one. Just as most amputees report what's known as "phantom limb," the feeling that their detached appendage is still there, surviving spouses frequently report seeing or sensing their departed partner. One 1971 survey in the *British Medical Journal* found that close to half the widows in Wales and England had seen their mates postmortem. These vivid encounters, which psychologists call "after-death communication," have long been among the most common kinds of paranormal experience, affecting skeptics and believers alike.

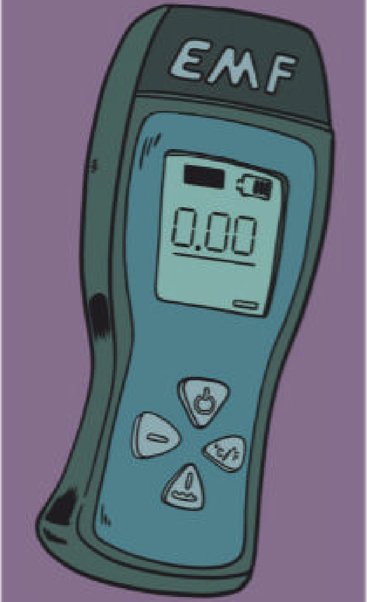
Experts think that such specters help us deal with painful or confusing events. A 2011 analysis published in the journal *Death Studies* looked at hundreds of incidents of supposed interaction with the deceased. The paper concluded that some occurrences provided "instantaneous relief from painful grief symptoms," while others strengthened preexisting religious views.

Death isn't the only trigger for a friendly ghost encounter either. Studies suggest kids who are bullied or exposed to dangerous situations are more likely to have paranormal fantasies, a trend psychologists also found in adults with a history of childhood trauma.

There's also evidence that sightings have other mental benefits. In a 1995 survey in *The Journal of the American Society for Psychical Research,* 91 percent of participants said their encounter had at least one upside, such as a sense of connection to others. So if you do see a shroud down the hallway, you might not want to run.

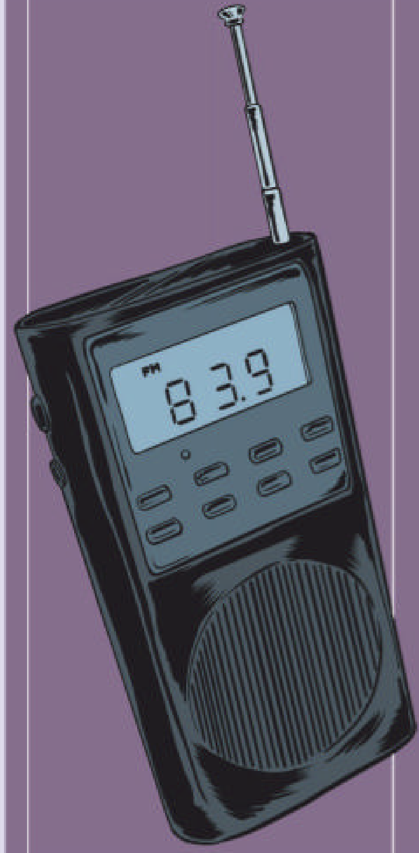
Tools of the Trade

Would-be ghost hunters use a host of gizmos, some more plausible than others, to sniff out spirits. These tools make up their arsenal.



Tape Recorder: Sleuths use both cassettes and digital devices to pick up "electronic voice phenomena." Almost any auditory oddity counts as an EVP, from crackles and thumps to spoken messages.

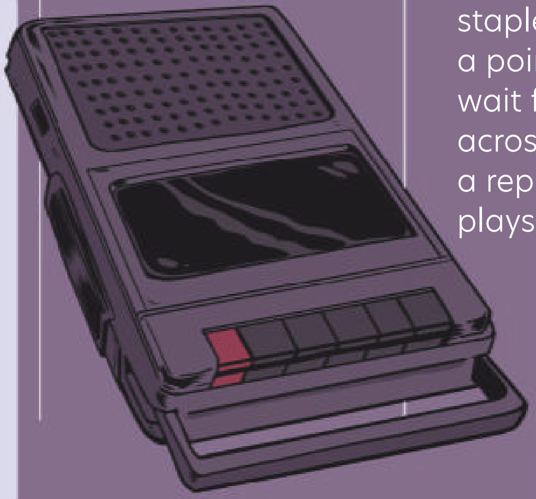
Electromagnetic Field Meter: Based on the theory that ghosts generate disturbances in background static, this gadget measures the strength of the force. Many appliances produce these currents as well.



Full Spectrum Camera: This clicker captures not just visible light but also infrared and ultraviolet frequencies. The broad range affords specter hunters crucial advanced night vision for midnight scouring.

Geiger Counter: Some spirit seekers think that haunts emit trace levels of radioactive material. Detectives tote this machine to identify and track the amount of these particles in the surrounding air.

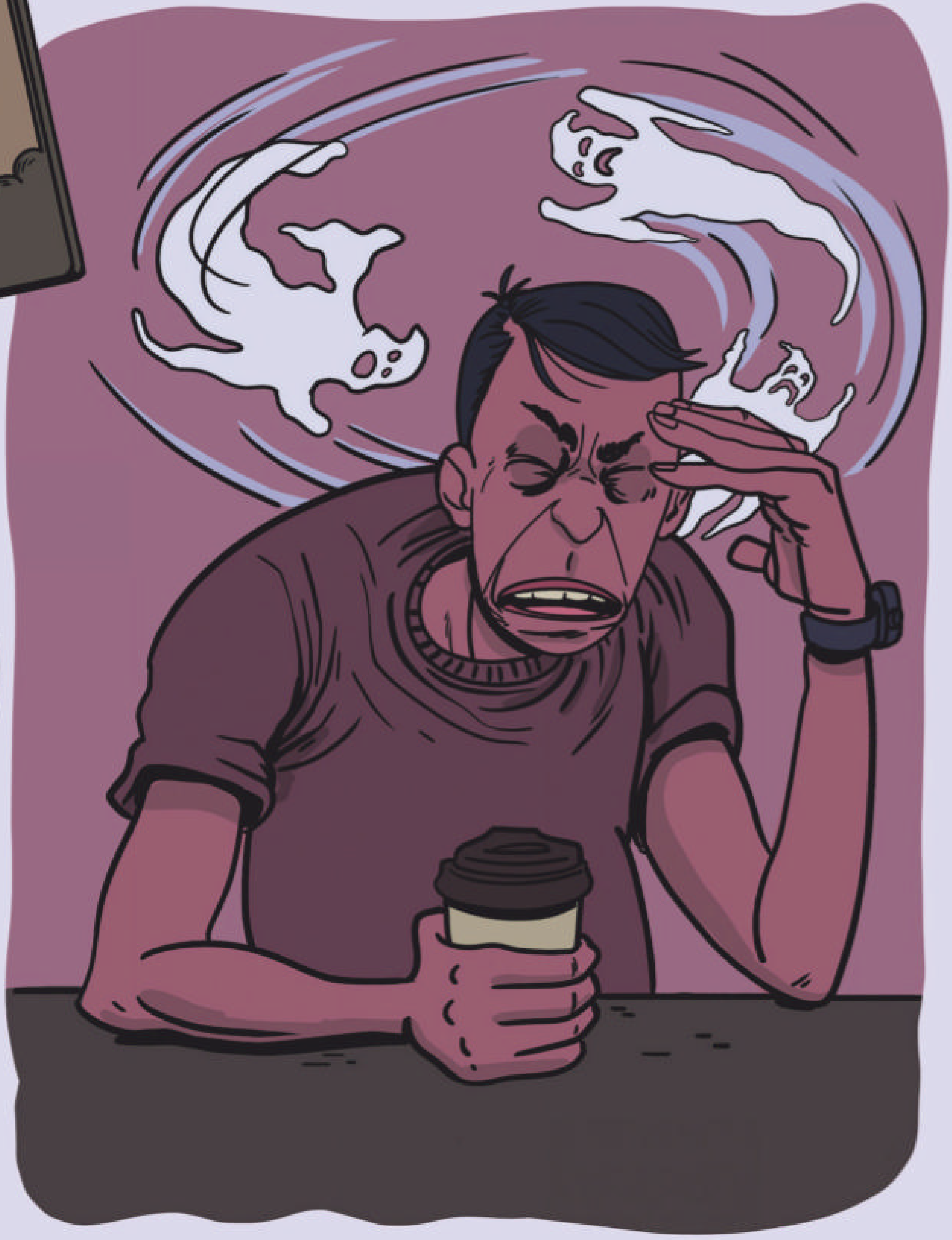
"Ghost Box": This phantom-finding radio scans AM and FM channels for abnormal signals. Since we're surrounded by soundwaves, it's easy for it to pick up noise that appears strange or otherworldly.

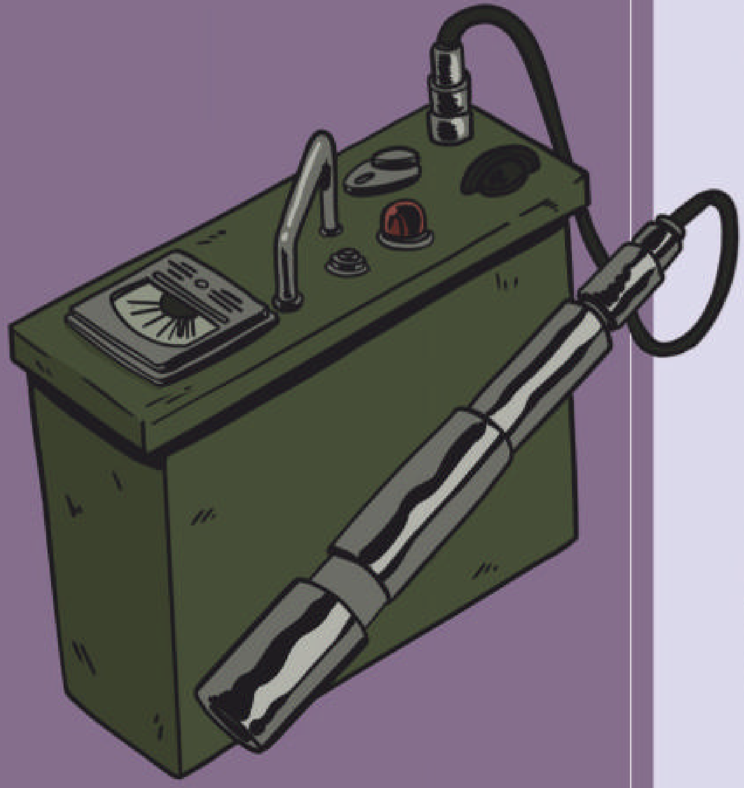


Ouija Board: In this sleepover staple, users put their hands on a pointer, ask a question, and wait for the planchette to move across the board and spell out a reply. Power of suggestion plays a big role in this game.

NAH
YAH
ABCDEFGHIJKLM
NOPQRSTUVWXYZ
1234567890
SMELL YA LATER

YOUR BRAIN IS UNWELL





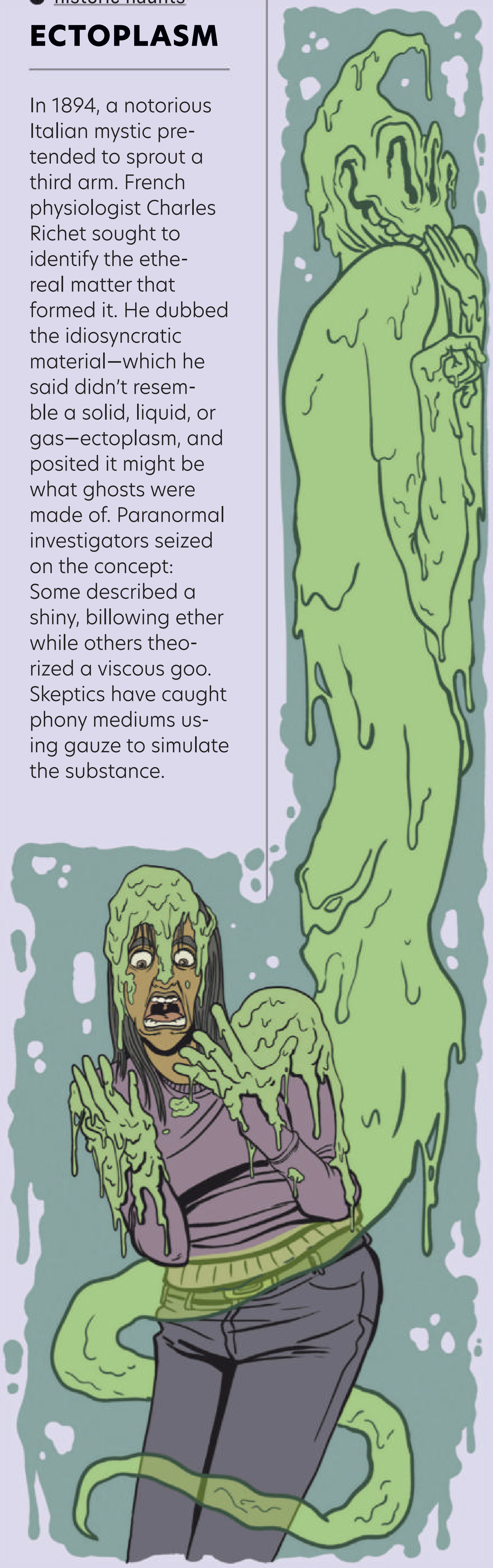
GHOSTLY OCCURRENCES CAN be the result of larger problems in our gray matter. For some, hearing voices or experiencing a vision can be an early indicator of medical conditions such as schizophrenia. Some evidence even suggests that people with underlying brain disorders tend to have paranormal confrontations that are more intense and negative than the average brush with the beyond.

Even in those without mental illness, temporary changes in brain activity can lead to run-ins with wraiths. People who experiment with psychoactive drugs like LSD and magic mushrooms frequently report spiritual fantasies. Furthermore, psychiatrists have deemed many visions the result of sleep paralysis, a poorly understood condition in which the afflicted wake up and find themselves unable to move. Scientists have yet to pinpoint the roots of this phenomenon, but some think it occurs when the brain crosses wires between conscious awareness and the dream-filled REM stage of slumber. This mixup is almost always accompanied by a sensation of entrapment, floating, or detachment from one's body—and in many cases sleepers see an accompanying demon or hag. According to a 2018 survey in the *International Journal of Applied and Basic Medical Research*, at least 8 percent of the general population and around 30 percent of people with psychiatric illnesses have reported having one of these nighttime episodes at some point in their lives. Many cultures even have a specific name for the ghoulish occurrence. In Cambodia, for instance, the freakish event is called "the ghost that pushes you down"; in Nigeria, meanwhile, locals have another name for it: "the devil on your back."

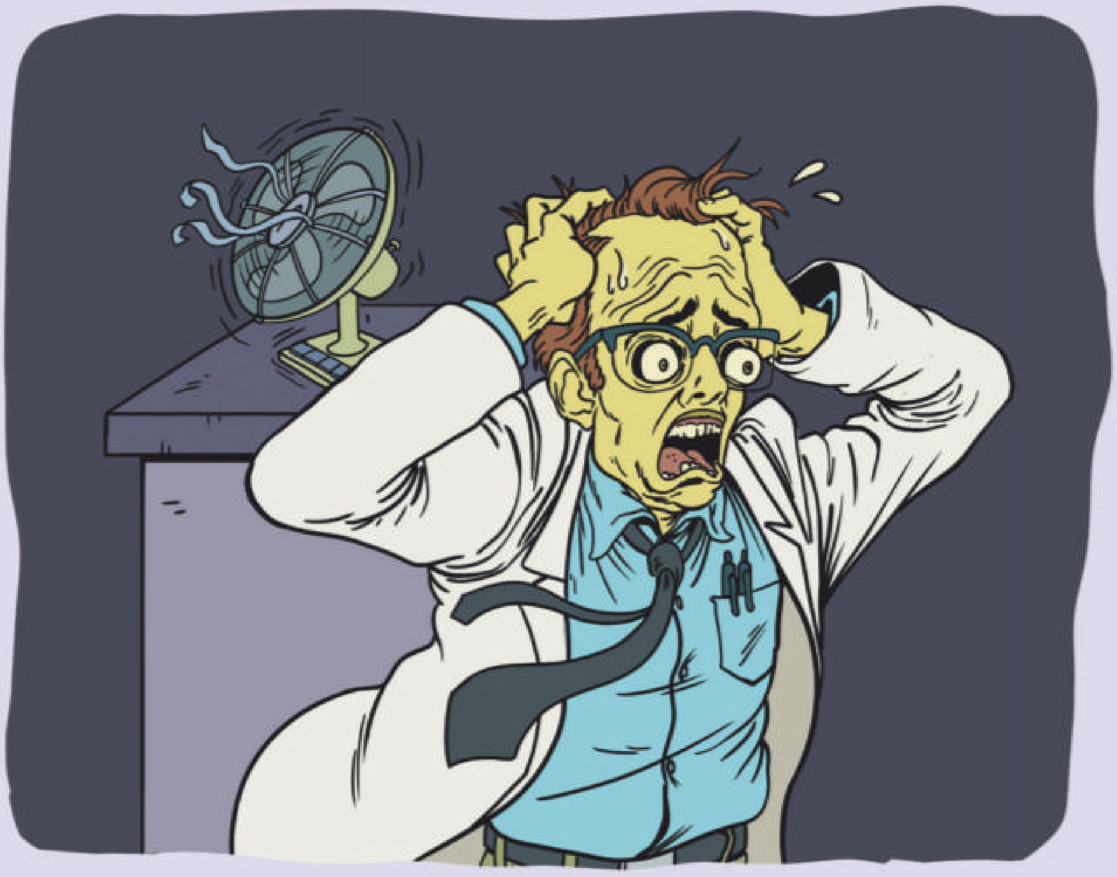
historic haunts

ECTOPLASM

In 1894, a notorious Italian mystic pretended to sprout a third arm. French physiologist Charles Richet sought to identify the ethereal matter that formed it. He dubbed the idiosyncratic material—which he said didn't resemble a solid, liquid, or gas—ectoplasm, and posited it might be what ghosts were made of. Paranormal investigators seized on the concept: Some described a shiny, billowing ether while others theorized a viscous goo. Skeptics have caught phony mediums using gauze to simulate the substance.



YOU'RE GETTING SOME BAD VIBRATIONS



SOMETIMES PEOPLE experience an otherworldly encounter simply because something in their environment is making a strange noise that sends their bodies into disarray.

In the early 1980s, British engineer Vic Tandy was working in the research lab of a medical supply company when a strange feeling came over him. All at once he felt frigid and overwhelmed with a sense of impending doom. As he paced around the room to calm down, he suddenly sensed an ethereal presence. Moments later, he was sure he saw a gray apparition in his peripheral view. When he whirled around, the specter was gone.

Tandy's colleagues had warned him the facility might be haunted, but the engineer was a skeptic by nature, so he scoured the place for an explanation. The culprit turned out to be a fan that hummed at a rate of 18.9 Hz. Though we can't sense their quivering, our eyeballs vibrate at a very similar frequency. The sound threw Tandy's vision for a loop and caused him to see a vague spook. The rogue fan may also have triggered his momentary panic, as studies suggest that certain noises can cause a person's organs to shake, which makes them hyperventilate.

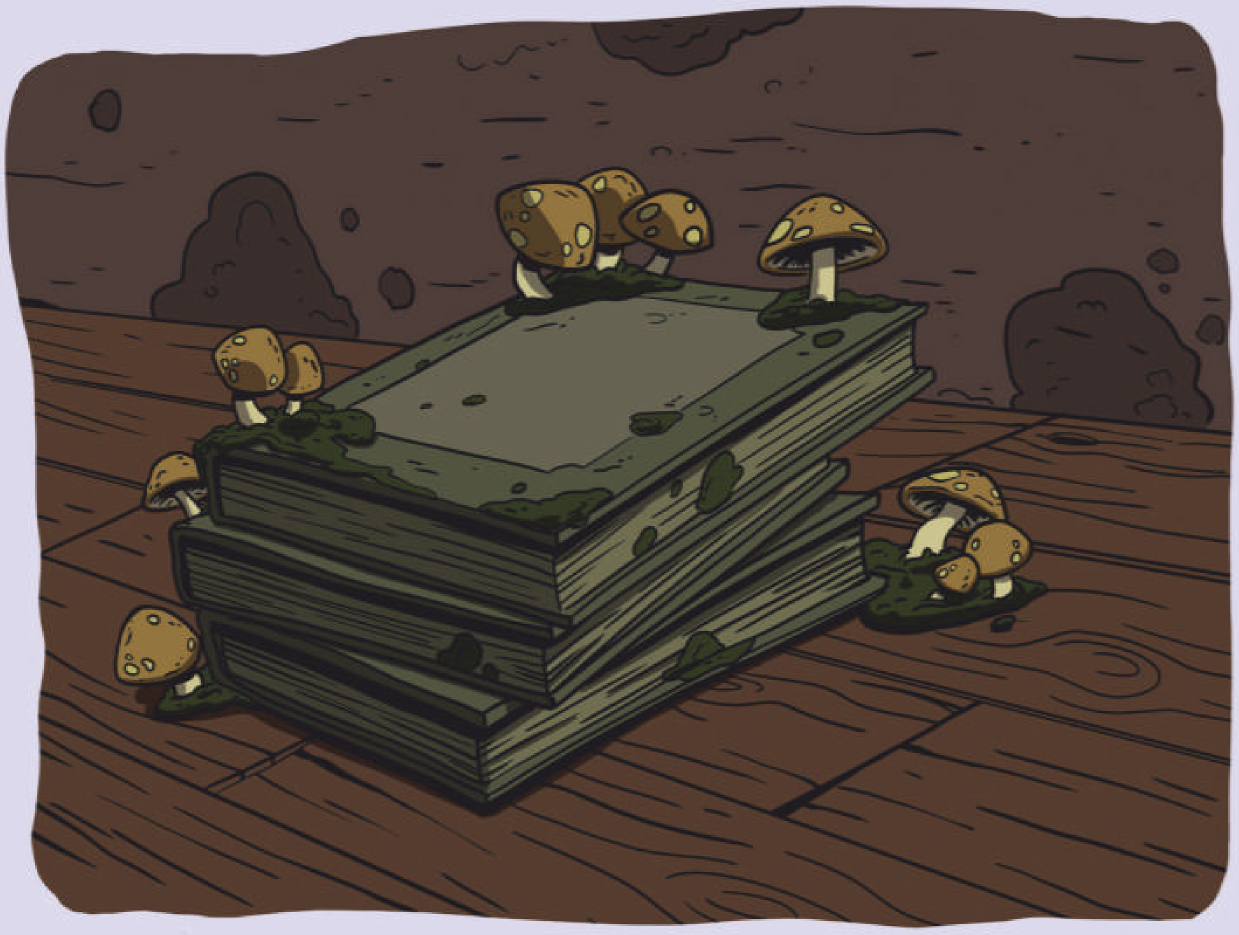
Waveforms that dwell around this acoustic sweet spot and below are known as infrasound. Though they're inaudible to human ears, whose range bottoms out at 20 Hz, the interval creates some fairly insidious side effects. In fact, after Tandy published his findings in 1998 in the *Journal of the Society for Psychical Research*, 18.9 Hz got a reputation as the "fear frequency."

Most of us don't regularly carry around audio gauges, so it's hard to know how many hauntings might be explained by a buzzing fan or a rumbling fridge. For Tandy, the fright left him more curious than ever about ghosts. "When it comes to supernatural phenomena," he told a reporter some years later, "I'm sitting on a fence."

● historic haunts

THE ENFIELD POLTERGEIST

Between 1977 and 1979, a malevolent spirit haunted a townhouse in the Enfield neighborhood of London—or so they say. Single mom Peggy Hodgson and her two children reported loud bangs and furniture moving of its own accord; when police arrived, they found 11-year-old daughter Janet speaking with a deep, guttural voice and seemingly bending spoons with her mind. More than two dozen people who visited the house described experiencing something odd. Later probes found Janet had made up much of it. A hidden camera caught her physically bending a spoon, and in later interviews she admitted to fabricating at least parts of the haunting. But family members and journalists, spurred by their own willingness to believe, ate the whole thing right up.



YOU'RE IN THE WRONG PLACE AT THE WRONG TIME

SITUATIONAL QUIRKS CAN easily manipulate our senses into seeing what's not there. Consider the rural town of Anson, Texas, where locals long believed that if you drove out to the crossroads nearest the local cemetery and flashed your headlights, a mysterious flicker would bounce back at you. Legend held that the blink came from the lantern of an ill-fated mother searching for her son. In 2011, a group of skeptics armed with iPhones and Google Maps confirmed a less evocative explanation: Cars coming around a bend on a nearby highway cast the eerie beams of light.

A far more troubling circumstantial peculiarity is the notion that mold and other pollutants—often found in old buildings—can mess with people's minds. Over the past few years, environmental engineering students at Clarkson University in Potsdam, New York, have been searching supposedly haunted structures across the Empire State for evidence of funky microbes; while it's too early to draw conclusions, the places they've visited seem to have higher spore counts than your average inhabited building. Believers often cite the smell of rotting food (which fungi and mildew gather on) as a solid indicator of a phantom visit, and there's some evidence that microscopic growths can trigger anxiety, depression, or even psychosis. Some historians believe that rye bread contaminated with ergot fungus (the same microbe from which LSD is derived) may have triggered the presumed possessions that led to the Salem witch trials of the late 1800s. Further, a dermatologist and known fungal expert at Guy's Hospital in London has theorized that moldering books could induce enough mental weirdness to have inspired some of literature's best works.

The same way scientists can potentially identify natural agents to explain "the devil's magic," known geologic phenomena may influence seemingly ghostly happenings. For example, some out-there theorists say that more sightings happen on days when Earth's geomagnetic activity takes a sudden plunge. Disturbances in the planet's magnetosphere, which are usually caused by anomalous outer-space events like solar flares, might mess with the inner workings of the brain, scrambling our perceptions in strange ways. So far, the evidence supporting this hypothesis is pretty thin.

A Ghost Lover's Reading List

Many cultures leave behind some kind of hair-raising yarn, whether it's a screamer intended to scare children or a complex metaphor about life. In addition to explaining things that go bump in the night, these standout sagas often help all of us cope with our fear of impending death and impart morals to future generations.

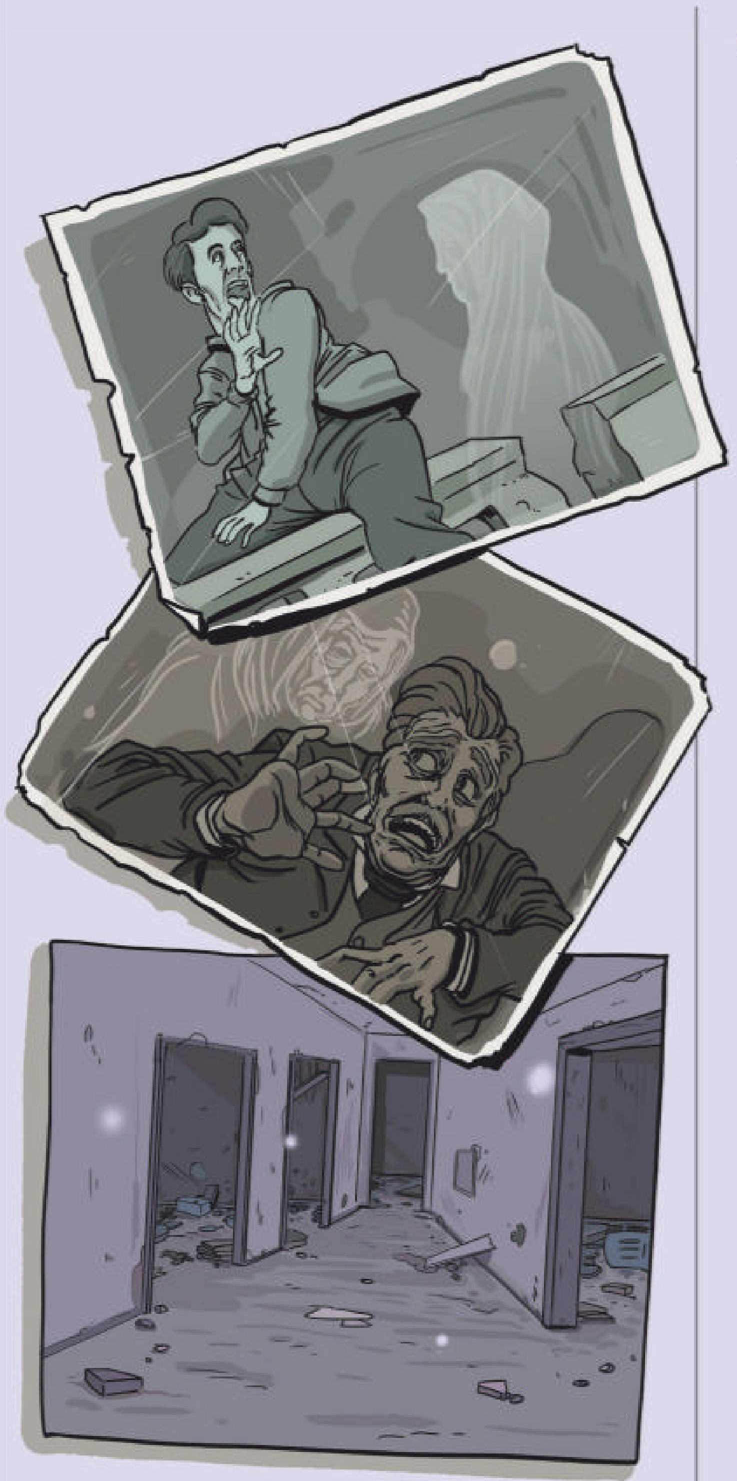
***A Ghost Story*:** Perhaps the earliest known spooky tale is an Egyptian parable found on tablets dating as far back as 1500 BCE. The narrative concerns a high priest who converses with a spirit called Nebusemekh. The wraith turns out to be a former tax collector who can't find his grave.

***Mostellaria*:** This 200 BCE play by Roman playwright Titus Maccius Plautus contains one of the first documented haunted houses. The drama follows a slave who hosts a party while the master is away. When the latter unexpectedly returns, the slave distracts him by insisting spirits are afoot.

***Strange Stories from a Chinese Studio*:** These vignettes enjoyed by 18th-century China's upper class show that paranormal stories can entail more than monsters under the bed. Pu Songling's satirical creatures torment stuck-up bureaucrats, often sending scorpions to sting their nethers.

***The Turn of the Screw*:** Henry James' 1898 novella moved away from the castles-and-vampires era of Gothic horror and introduced a new genre of psychological spookiness. A nanny of two kids on a country estate loses her mind after she experiences repeated visits from a spectral couple.

***My Life in the Bush of Ghosts*:** In this 1954 epic by the Nigerian writer Amos Tutuola, a boy finds himself in a vast plain with malevolent forces from West African Yoruba folklore. The child wanders among the phantoms for so long he marries twice. The yarn introduced Yoruba tales to Western audiences.



● historic haunts

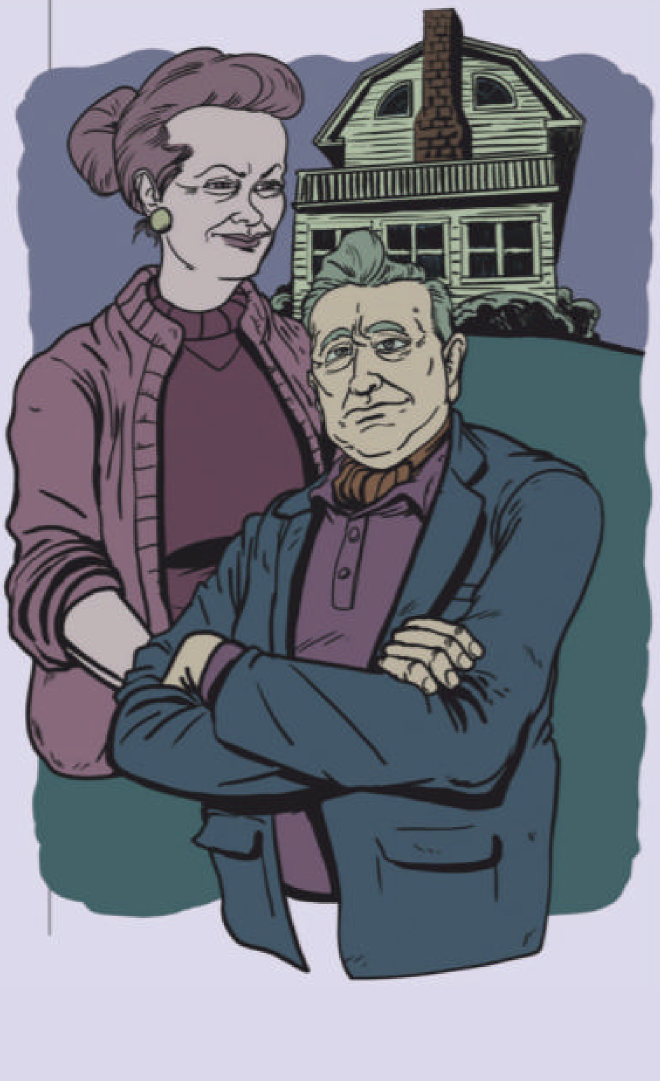
SINISTER SNAPSHOTS

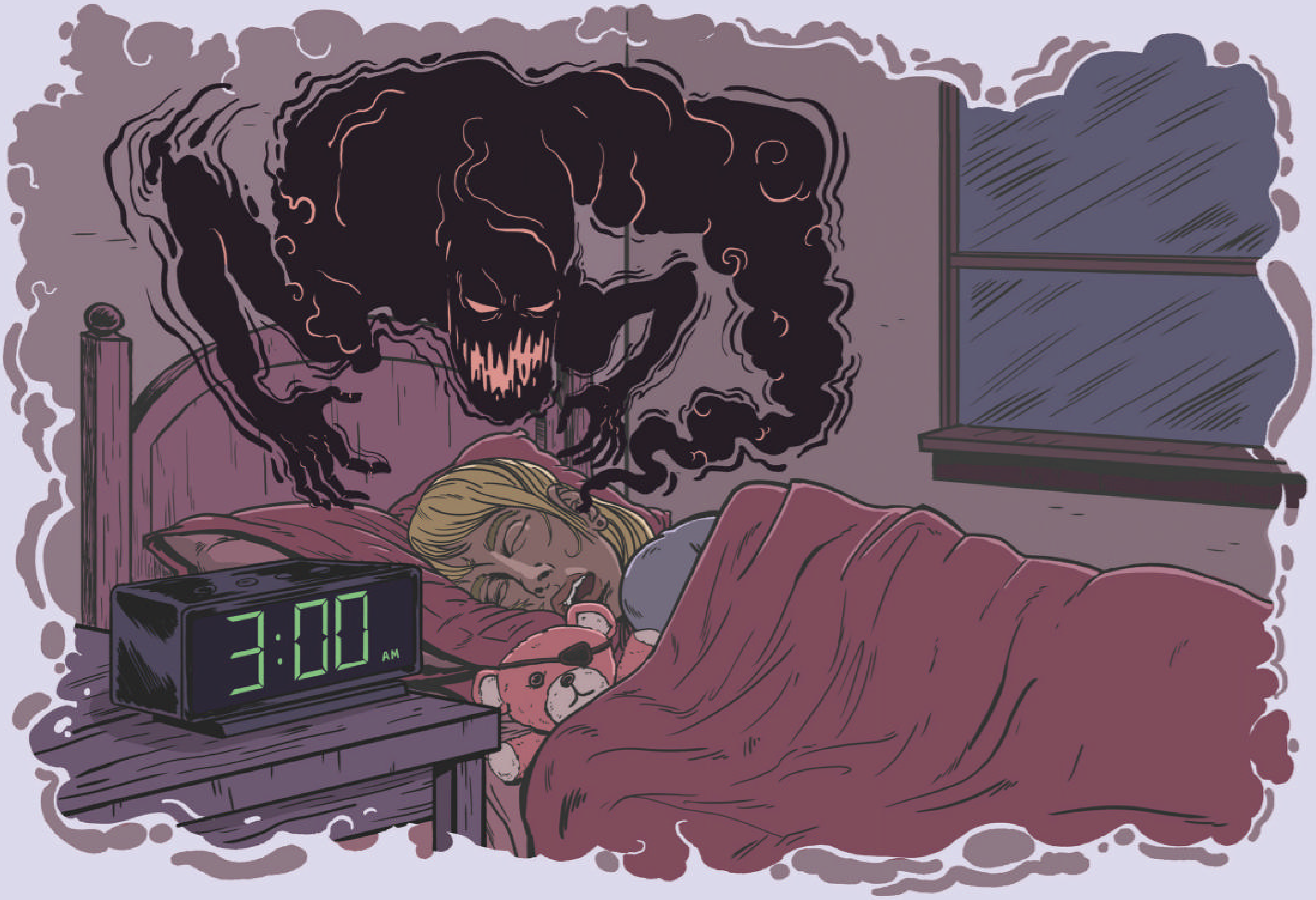
The rising death toll of the American Civil War helped spur a genre of posed portrait in the late 19th century: A living person would sit for a picture, and the photographer would later splice in a half-transparent still of a deceased spouse or child, showing the long-gone loved one hovering in the background. At first these productions were considered keepsakes, but they gave rise to elaborate forgeries that claimed to show real spectral visitations, supposedly captured thanks to newfangled camera technology. Nowadays we know better, but photographic trickery isn't dead yet. Many ghost hunters claim that spirits appear on digital shots in the form of "orbs," even though camera engineers say those are probably just specks of dust illuminated by the flash.

● historic haunts

AMITYVILLE

In 1979, before TV shows like *Ghost Hunters*, paranormal investigators Ed and Lorraine Warren captured America's imagination when they took a deep dive into the Amityville haunting. It was a gruesome incident wherein an allegedly possessed Long Island man murdered his parents and siblings. The couple's well-documented coverage of the case, which led to a storm of credulous media attention, went on to inspire nearly two dozen films, including the wildly popular *Conjuring* series. But the Warrens were never able to produce evidence of the encounters. In the 1990s, Steven Novella and Perry DeAngelis, a neurologist and a podcaster, respectively, scrutinized artifacts, such as cursed dolls and demon masks, in the Warrens' Connecticut-based Occult Museum and dismissed them as blarney. The Warrens may have believed they were talking to spirits, but no one else should.





YOUR MIND IS PLAYING TRICKS ON ITSELF

IN RECENT YEARS, NEUROLOGISTS HAVE identified potential bases for the feeling that someone or something is haunting us.

Research suggests seizures in the temporal lobe—the area of your noggin that processes visual memory and spoken language—might trigger ghost sightings. Electrical disturbances in this brain area could make us feel connected to otherworldly realms. Patients who have a history of such problems are more likely to report paranormal beliefs; furthermore, supernatural experiences tend to cluster between 2 a.m. and 4 a.m., which some studies suggest is when these seizures occur most often.

Gray matter researchers have also spotted similar activity in controlled laboratory settings. A 2016 case study by doctors at a Jerusalem hospital described a patient who had a spontaneous religious experience as physicians stimulated his temporal lobe while treating him for epilepsy. And a 2008 paper published in the *International Journal of Yoga* found that people with supposed telepathic powers exhibited unusual activity in a section of the lobe called the right parahippocampal gyrus—one of a pair of regions that handle memory—when they tried to complete a mind-reading task.

Other sections of our headspace can also fall victim to phantom confusion. In a 2014 study, Swiss neuroscientists blindfolded a group of participants, then hooked up their hands to a machine that tracked finger movement. When the subjects moved their arms, a robotic appendage behind them simultaneously touched their backs in the same fashion. But when investigators delayed the mimicking movements of the animatronic device by just a few milliseconds, several people reported sensing an intelligent presence behind them, as if a spirit were poking them in the back. The researchers think the stalled movements wreak havoc on how the brain times incoming signals in the frontoparietal cortex, which controls inbound sensory and motor cues. Later imaging on folks who reported sensing paranormal shadows in the past found many had lesions in that exact area of gray matter, affecting its normal functioning.

This "feeling of a presence" phenomenon has more general implications for the hard-to-study field of the paranormal too. If a tiny movement delay is enough to conjure up spirits, perhaps our brains are predisposed at some deep level to imagine ghosts are walking among us. We might grow up, but those feelings never go away.

CLEARING

A new generation of satellites can sniff out unidentified methane emitters, adding a sharper tool against climate change.

THE AIR

By Paul Tullis

ON JANUARY 13, 2019, while trying to measure the greenhouse gas output of a mud volcano in Turkmenistan, a microwave-size satellite known as Claire stumbled upon something unexpected: an enormous cloud of methane spilling into frame from an area just south of the peak. "We couldn't believe something that large was actually there," says Stephane Germain, the CEO and co-founder of GHGSat, the Montreal-based company that operates Claire. Curious as to where it could be coming from, Germain and colleagues looked at images of the area and zeroed in on a gas facility called Korpezhe. The source of the pollution seemed to be a pipeline.

Through diplomatic channels, the company passed the information to Turkmen officials. Flying over Korpezhe a few months later, Claire found the plumes had disappeared. The assumption is that they'd come from leaky equipment that site managers had been able to patch.

Claire's discovery points to a novel means of solving a mystery that has far-reaching implications for the climate: What are the specific sources that are contributing to a dangerous increase in the powerful greenhouse gas methane, whose atmospheric concentration has nearly doubled in less than 70 years?

Environmentalists and policy makers concerned about climate change have focused for decades on carbon dioxide, the most abundant greenhouse gas. When scientists started ringing alarms about its rising levels 40 years ago, it looked as if we still had time to compel sectors responsible for the bulk of CO_2 emissions, including transportation and energy, into action. The hope was that regulations, such as stiffer gas mileage requirements on vehicles and penalties for companies that use the atmosphere as a dumping ground, would incentivize reductions. But cap-and-trade markets in Quebec, California, and Europe plus the voluntary Paris Agreement of 2015 have not been enough to limit global warming's effects, now evident in Australia's burning forests and Houston's flooded streets. "If you want to do something in time to meet the Paris targets, you need a faster response," says Bill Hirst, a physicist who until June 2020 was the principal scientist for atmospheric monitoring at the gas-and-oil giant Shell.

That urgency makes methane, or CH_4, arguably a more important target in the short term. Carbon dioxide lingers in the atmosphere for 100 years or more, so curbing its emissions won't affect the climate at least until the 2100s. Methane, on the other hand, starts breaking up after a decade, but over 20 years, it's 84 times as potent as CO_2. Dial it down, and you'll see results by the time Greta Thunberg can get a Ph.D. "Dramatically reducing or even zeroing industry CH_4 emissions should be a no-brainer," says Gabrielle Pétron, an affiliate research scientist at the Carbon Cycle Group of the National Oceanic and Atmospheric Administration.

Since 2009, satellites, including ones serviced by NASA, have been circling the globe quantifying greenhouse gases for climate modeling. But those orbiters were designed to measure concentrations of emissions across the entire planet, not to identify specific sources, like a leaking valve in a pipe in Turkmenistan. Claire is part of a generation of smaller, cheaper spacecraft that are now in flight, ready to launch, or on the drawing board. The newer models boast higher-resolution equipment, able to pinpoint the origin of a discharge.

To be sure, there are other methods for cataloguing methane. Just three years ago, driving around in a car with a gas detector affixed to the roof was considered state of the art. But given the limited speed of an automobile, that's practical only if you have a target in mind—and to get close enough, in many cases you'd need permission from suspected polluters. Planes and hot-air balloons cover a bit more ground, but they're still pretty localized, and to track changes you'd need to fly again and again, which gets expensive. Satellites like Claire circle Earth every day.

CLAIRE WAS AN international effort. The University of Toronto's Space Flight Laboratory designed and built it, and the Indian Space Research Organisation launched it from a site near the southeastern coastal city of Chennai in June 2016. A 353-ton, 145-foot-tall rocket carried 20 satellites to photograph, map, and take the temperature of Earth and certain points on its surface—a far-reaching remote sensing mission.

Almost a third of the way around the globe, 8,265 miles away in Toronto, Daniel Kekez, an electronics and software developer at the flight lab, anxiously watched the launch broadcast. He was in charge of Claire's commissioning process—powering it up and beginning to put it through its paces. Though the Indians had provided him with an estimate of where they would inject Claire into space, he needed to wait until the satellite,

18+

WHAT IS
AVAXHOME?

AVAXHOME -

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

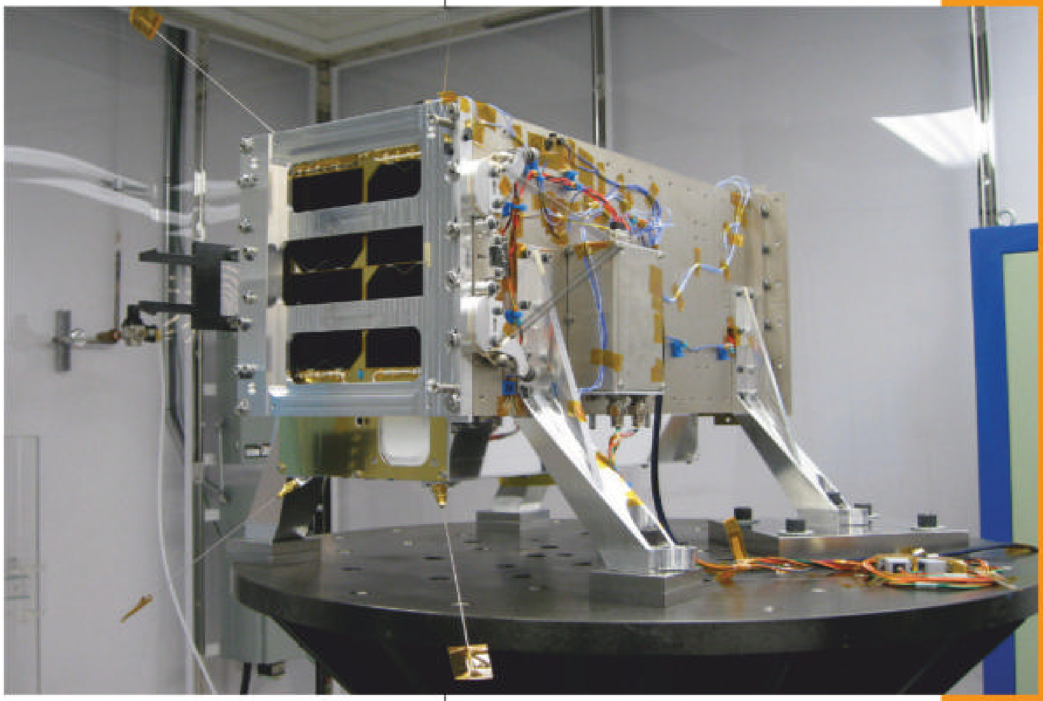
18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu



Claire, shown during prelaunch testing, has an imaging spectrometer to measure methane.

COURTESY OF GHGSAT INC.

officially known as Sat-D, passed over Toronto, the site of the only ground station licensed to transmit to it. Once Claire was within range, he could attempt to make contact. "We communicate in the blind, hoping it will respond," Kekez says. It did, on the first try.

Then it was time to see if Claire could do what it was designed to. Over the next several weeks, Kekez and his colleagues grabbed measurements as it sailed over methane sources—coal mines, gas facilities—whose quantity of emissions they already knew, just to check that the instruments worked properly.

Claire measures methane using a device called an imaging spectrometer, which is essentially a camera that is sensitive to wavelengths of light invisible to humans. Those on satellites can measure ultraviolet, near-infrared, or shortwave infrared beams from the sun bouncing back off Earth. Different gases absorb specific wavelengths of light, so researchers can determine how much CH_4 or CO_2 there is at a particular location based on how much signal in those bands makes it to the spectrometer. Shortwave infrared reveals CH_4 information. Of course, there are all sorts of confounding factors. Earth's reflectivity is greater in the Sahara Desert, for instance, than elsewhere; to the untrained eye, this makes it look as if a giant methane cloud hovers over North Africa, larger than is plausible, given the production capacity of Algeria and Libya. Aerosols—tiny particles of solids or liquid suspended in air and clouds—are another pain. Operators study the near-infrared band to figure out what's aerosol and what's methane.

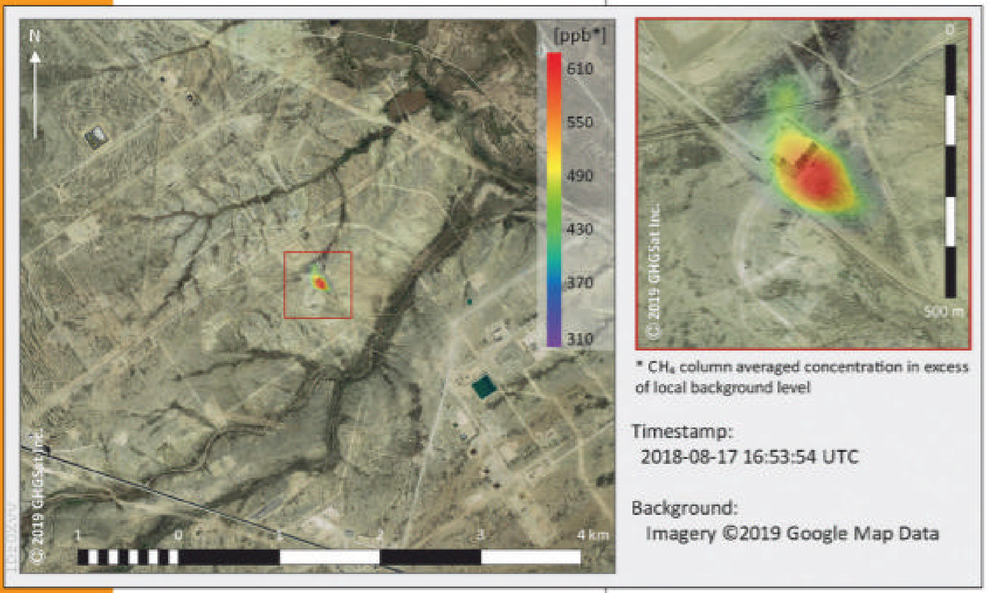
The case for targeting CH_4 has been growing. In a paper published in February 2020 in *Nature*, University of Rochester geoscientist Benjamin Hmiel found that environmental scientists and atmospheric chemists may have been underestimating the increase in concentrations of the gas since the beginning of the industrial era by a factor of 10. Research into the reason for the recent spike continues: It might be a function of changes in how the atmosphere processes CH_4, or the result of human activity, such as oil and gas production. "The only way to reduce this uncertainty," according to the International Energy Agency, an intergovernmental organization in Paris, "is to continue to improve data transparency." Precisely what GHGSat and others are trying to do.

What is certain is that the energy industry has been miscounting its contribution. "No one wants to spend money to measure what they're not required to," says Hirst, the atmospheric monitoring expert. Companies report rough calculations of facility emissions, but Hirst says these figures are "a glorified guess," mainly because they don't account for fugitive emissions (i.e., leaks).

Pretty much anytime anyone has looked, it's turned out that the CH_4 emissions from oil and gas operations in the United States, the world's largest oil producer, are far higher than what the industry or the Environmental Protection Agency—including under President Obama—has estimated. Sixty percent higher, according to research published in *Science* in 2018. (Only Norway maintains stringent regulatory standards and a stiff tax on methane released in production, so there's no reason to believe other international operators are any better than those in the US.) An April 2020 report in *Science Advances* found the biggest methane source ever—2.8 million tons per year—above the more than 7,000 fields of oil and gas in the Permian Basin, which straddles Texas and New Mexico. Co-author Sudhanshu Pandey, an atmospheric scientist with the SRON Netherlands Institute for

Space Research, which analyzes CH$_4$ data from European Space Agency satellites, says, “What we see is that the emissions here are more than two times higher than what the estimation methods were predicting.”

Claire’s images of methane leaks (enlarged at right) over the Permian Basin in the southwest US.



* CH$_4$ column averaged concentration in excess of local background level

Timestamp:
2018-08-17 16:53:54 UTC

Background:
Imagery ©2019 Google Map Data

COURTESY OF GHGSAT INC.

ON THE DAY of its Turkmenistan discovery, Claire was testing its spectrometer by flying over a known methane release from the mud volcano. Occasionally GHGSat takes measurements over such a source to check the sensitivity of its instrument. Claire had flown over this peak before, and operators had assumed that the plume at the edge of the images they’d collected was a distortion—“noise” from surface reflectivity or aerosols skewing the reading. Upon closer inspection, though, it seemed this wasn’t just interference, and they decided to see if the European Space Agency’s monitoring instrument Tropomi could validate the discovery.

Tropomi is the spectrometer aboard the ESA satellite that keeps tabs on greenhouse gases; it constantly photographs Earth’s surface to quantify all the methane in the atmosphere. Its field of view stretches almost the equivalent of New York to Denver, with each pixel covering what would be nearly 1,000 blocks in Manhattan. That’s great for seeing large concentrations of CH$_4$—places where it’s accumulating because of wind or other factors, which are not necessarily where the gas is coming from. (By comparison, Claire’s field of view is only about the size of San Francisco, with each pixel a little smaller than an average supermarket—ideal for spotting leaks.) The agency had never worked with GHGSat before, but was happy to look for the plume in its own data. As Germain had predicted, Tropomi picked up the signal from Turkmenistan. It was the largest leak ever recorded—almost half again as large as the previous record holder, from a 2015 accident at a natural gas storage facility in Aliso Canyon, California.

Going over satellite photographs of the area, Germain’s colleagues found methane clouds that corresponded to the spots in the energy facility where natural gas gets compressed for transport and where it’s purified, as well as at the pipeline connecting the two sites. Once alerted, the plant ended the emission—an unexpected move in the former Soviet republic that Human Rights Watch has called “virtually closed to independent scrutiny,” and that has a single, state-owned gas company accountable to no one.

Such large bleeds are rare but have big effects: According to 2016 research published in *Environmental Science & Technology*, half of fugitive emissions come from just 5 percent of methane leaks—things like loose valves, Germain says. The US alone has around 1 million oil-and-gas facilities, each with possibly hundreds or thousands of valves; even 5 percent of that is too many to locate or monitor from the ground.

Now GHGSat and the ESA work together to locate leaks. Whenever the team running Tropomi finds an anomalously large plume, it tips GHGSat to go check it out. With such a tight field of view, Claire can zoom in on the spot where the ESA has detected a concentration. Operators on the ground then take the image spectrometry from Claire, calculate the effect of wind speed and direction on the found gas plume, and determine where it’s coming from. Since Turkmenistan, Germain says, “We’ve found several other sources, and we’re working with the operators to get those emissions reduced.”

MORE SATELLITES LIKE Claire are on the way. In September 2020, GHGSat expected to launch Iris, which can pinpoint emissions one-tenth the size of those

Claire can spot. The Environmental Defense Fund is planning its own orbiter, MethaneSAT, which will combine a field of view about a tenth of Tropomi's with a precision its backers describe as unprecedented. Taking off in 2022, it will make weekly sweeps of the areas of the globe that account for 80 percent of all oil and gas production. Germany and France are collaborating on Merlin, which, when it goes up in 2024, will use lidar—a technology popularized by self-driving car navigation that works like radar, but with light instead of sound—to scan through clouds and distinguish methane from water vapor and surface reflectivity. Bluefield, a company based in New York City, is planning a constellation of 10 satellites even smaller than Claire by 2023. These will measure the gas with a spectrometry technique it contends will be more sensitive than the one other orbiters use. (The US has been a laggard in climate-focused remote sensing from orbit since a Republican administration mothballed the Deep Space Climate Observatory in 2001, delaying its launch by more than a decade.)

Some of these satellites will service governments that signed on to the Paris accord. Others will sell their data to oil and gas companies that want to reduce their emissions in order to shrink what they owe to cap-and-trade markets, in which energy producers and others pay for the greenhouse gases their operations generate. Companies may also want to improve their reputations among consumers, or figure out if it's worth the investment to capture and sell methane as energy. Natural gas, which provides about 38 percent of the electricity in the US, is virtually all CH_4.

The value of the gas that drillers leak hits $2 billion annually, according to estimates published in *Science*. A June 2020 report from the independent research group Institute for Energy Economics and Financial Analysis found that Texas oil companies wasted $749 million venting methane in 2018; the Texas Railroad Commission, the state regulator with oversight, declined to take action. In fact, the International Energy Agency says the global industry could reduce methane leaks by 75 percent—about a third of it at no net cost, since it could finance the fixes by selling much of what it recovers.

Once we figure out the whos and wheres of methane emissions, what do we do with all that data? One idea is a dedicated cap-and-trade scheme for the gas. The one the European Union uses regulates various greenhouse gases but not CH_4 yet. California and Quebec lump it with CO_2 as a "carbon-dioxide equivalent," as the EU does with nitrous oxide and perfluorocarbons. But Adam Hawkes, director of the Sustainable Gas Institute at Imperial College London, argues in a 2018 paper that conflating the two doesn't account for methane's greater short-term global warming potential.

"WITHIN A FEW YEARS THEY'LL SHOW HOW BAD THESE SOURCES ARE." —BILL HIRST

Hans Stegehuis, a former hedge fund trader who works on financial markets and operational risk at Dutch bank ABN Amro, has an idea (his own, not his bank's) for a methane-trading system modeled on the EU's current scheme, but that learns from what he views as its major mistakes. These, he says, include an oversupply of emissions credits that pushed down the price and therefore disincentivized reductions, and variations in how countries estimate such releases. For example, a landfill in the United Kingdom miraculously emits—on paper—a tenth of the methane produced by an identical facility in Germany. Stegehuis' system would reduce the supply of credits, solving the first problem. Satellites would address the second, he says, because "now you can quantify who's emitting what." He envisions a fund set up from the proceeds of overage fines to help finance the development of methane abatement technologies.

"I think I'd encourage" measures like the one Stegehuis proposes, says Richard Sandor, an economist at the University of Chicago Law School who initiated cap-and-trade markets for carbon. But new financial markets require more than just a good idea. "It takes a decade to build

(CONTINUED ON PAGE 107)

ADVERTISEMENT

Men's Virility Restored in Clinical Trial; 275% More Blood Flow in 5 Minutes

A newly improved version of America's best-selling male performance enhancer gives 70-year-old men the bedroom performance they enjoyed in their 30's.

America's best-selling sexual performance enhancer just got a lot better.

It's the latest breakthrough for nitric oxide – the molecule that makes erections possible by increasing blood flow to your penis.

Nitric oxide won the Nobel Prize in 1998. It's why "the little blue pill" works. More than 200,000 studies confirm it's the key to superior sexual performance.

And this new discovery increases nitric oxide availability resulting in even quicker, stronger and longer-lasting erections.

One double-blind, placebo-controlled study (the "gold-standard" of research) involved a group of 70-year-old-men.

They didn't exercise. They didn't eat healthy. And researchers reported their "nitric oxide availability was almost totally compromised," resulting in blood flow less than HALF of a man in peak sexual health.

But only five minutes after the first dose their blood flow increased 275%, back to levels of a perfectly healthy 31-year-old man! "It's amazing," remarks nitric oxide expert Dr. Al Sears. "That's like giving 70-year-old men the sexual power of 30-year-olds."

WHY SO MUCH EXCITEMENT?

Despite the billions men spend annually on older nitric oxide therapies, there's one well-known problem with them.

They don't always work.

Dr. Joseph Loscalzo explains why. He's studied nitric oxide for over 43 years. He is the physician-in-chief at Brigham and Women's Hospital. He says a "deficiency of bioactive nitric oxide… leads to impaired endothelium-dependent vasorelaxation."

In plain English, these older products may increase levels of nitric oxide. But that's only half the battle. If it's not bioactively available then your body can't absorb it to produce an erection.

Experts simply call it the nitric oxide "glitch." And until now, there's never been a solution.

NEXT GENERATION NITRIC OXIDE FORMULA FLYING OFF SHELVES

Upon further research, America's No. 1 men's health expert Dr. Al Sears discovered certain nutrients fix this "glitch" resulting in 275% better blood flow.

He's combined those nutrients with proven nitric oxide boosters in a new formula called *Primal Max Red*. In clinical trials, 5,000 mg is required for satisfying sexual performance. *Primal Max Red* contains a bigger, 9,000 mg per serving dose. It's become so popular, he's having trouble keeping it in stock.

Dr. Sears is the author of more than 500 scientific papers. Thousands of people listened to him speak at the recent Palm Beach Health & Wellness Festival featuring Dr. Oz. NFL Hall of Fame quarterback Joe Namath recently visited his clinic, the **Sears Institute for Anti-Aging Medicine.**

Primal Max Red has only been available for a few months — but everyone who takes it reports a big difference. *"I have the energy to have sex three times in one day, WOW! That has not happened in years. Oh, by the way I am 62,"* says Jonathan K. from Birmingham, AL.

HOW IT WORKS

Loss of erection power starts with your blood vessels. Specifically, the inside layer called the endothelium where nitric oxide is made.

The problem is various factors THICKEN your blood vessels as you age. This blocks availability causing the nitric oxide "glitch." The result is difficulty in getting and sustaining a healthy erection.

How bad is the problem?

Researcher shows the typical 40-year-old man absorbs 50% less nitric oxide. At 50, that drops to 25%. And once you pass 60 just a measly 15% gets through.

To make matters worse, nitric oxide levels start declining in your 30's. And by 70, nitric oxide production is down an alarming 75%.

Primal Max Red is the first formula to tackle both problems. Combining powerful nitric oxide boosters and a proven delivery mechanism that defeats the nitric oxide "glitch" resulting in 275% better blood flow and stronger erections. There's not enough space here to fully explain how it works, so Dr. Sears will send anyone who orders *Primal Max Red* a free special report that explains everything.

MORE CLINICAL RESULTS

Nutrients in *Primal Max Red* have logged impressive results.

In a *Journal of Applied Physiology* study, one resulted in a 30 times MORE nitric oxide. And these increased levels lasted up to 12 hours.

"I measured my nitric oxide levels, you can buy a test kit from Amazon," reports 48-year-old Jeff O. "Monday night I showed depleted."

Then he used ingredients in *Primal Max Red* and, "The results were off the charts. I first woke around 3 a.m. on Tuesday with a throbbing boner. My nitric oxide levels measured at the top end of the range."

A new discovery that increases nitric oxide availability was recently proven in a clinical trial to boost blood flow 275% resulting in even quicker, stronger and longer-lasting erections.

FREE BONUS TESTOSTERONE BOOSTER

Every order also gets Dr. Sears testosterone boosting formula *Primal Max Black* for free.

"If you want passionate 'rip your clothes off' sex you had in your younger days, you need nitric oxide to get your erection going. And testosterone for energy and drive," says Dr. Sears. "You get both with *Primal Max Red* and *Primal Max Black*."

HOW TO GET PRIMAL MAX

To secure free bottles of *Primal Max Black* and get the hot, new *Primal Max Red* formula, buyers should contact the Sears Health Hotline at 1-800-236-3103 within the next 48 hours. "It's not available in drug stores yet," says Dr. Sears. "The Hotline allows us to ship directly to the customer."

Dr. Sears feels so strongly about Primal Max, all orders are backed by a 100% money-back guarantee. "Just send me back the bottle and any unused product within 90 days from purchase date, and I'll send you all your money back," he says.

The Hotline will be open for the next 48 hours. After that, the phone number will be shut down to allow them to restock. Call 1-800-236-3103 to secure your limited supply of *Primal Max Red* and free bottles of *Primal Max Black*. You don't need a prescription, and those who call in the first 24 hours qualify for a significant discount. Use Promo Code POP1020PMAX when you call in. Lines are frequently busy, but all calls will be answered.

THESE STATEMENTS HAVE NOT BEEN EVALUATED BY THE FOOD AND DRUG ADMINISTRATION. THIS PRODUCT IS NOT INTENDED TO DIAGNOSE, TREAT, CURE OR PREVENT ANY DISEASE.
RESULTS MAY VARY FROM PERSON TO PERSON. NO INDIVIDUAL RESULT SHOULD BE SEEN AS TYPICAL. OFFER NOT AVAILABLE TO RESIDENTS OF IOWA

TALES FROM THE FIELD

PG 95 | DATE: FALL 2020 | POPSCI.COM | ILLUSTRATIONS BY TIM ENTHOVEN

E.T., please phone our home

SOFIA SHEIKH, PHD CANDIDATE IN ASTRONOMY AND ASTROBIOLOGY AT PENNSYLVANIA STATE UNIVERSITY

The search for extraterrestrial intelligence has progressed rapidly in the past few decades. Back in the 1960s, researchers would literally tune the radio dial, hoping to hear artificial patterns in the static that would prove we're not alone. But they could only listen to one slice of the spectrum at a time. Now, thanks to massive radio telescopes, astronomers can pick up wide swaths of it at once. Breakthrough Listen, a global research group I am part of, is investigating more than a million stars for single-tone signals akin to our AM/FM stations.

In 2017, I led a study of 20 intriguing stars—ones from which Earth's transit in front of our sun is visible. If a civilization in this zone can see us, perhaps they're reaching out. It took almost five months for every star to rotate into view and another two years to sort through the hundreds of gigabytes of radio crackling we gathered.

During my analysis, one tone seemed powerful and clear, as you would expect an artificial transmission to be. But when I looked more closely, I noticed that the signal's frequency barely shifted. This implies its source is stationary relative to the telescope rather than zooming around as a planet, moon, or spacecraft would. My money's on something like a cell tower. That's 20 stars down, millions to go.

as told to Charlie Wood

hidden pictures

SILVIA A. CENTENO, RESEARCH SCIENTIST AT THE METROPOLITAN MUSEUM OF ART IN NEW YORK

Pablo Picasso's noted portrait of literary icon Gertrude Stein has long mystified art historians. Between the fall of 1905 and the spring of 1906, the author sat for the artist more than 80 times—an atypically lengthy process for the accomplished painter. Contemporary reports suggest Picasso kept restarting his work.

For years chemists and conservators have been trying to unravel the artist's tedious creative process. In earlier studies, researchers placed the artwork in an X-ray machine, which identifies the presence of heavy elements common in pigments, such as mercury and lead. If Picasso painted over something, it would reveal what's underneath. But X-rays can only detect dense metals, so the studies unveiled just a handful of edits.

In 2019, MET conservator Isabelle Duvernois and I used a newer technology called macro X-ray fluorescence, which finds elements too light for other imaging modes to pick up, such as calcium and phosphorus. It exposes the work to specific radiation that excites the atoms in pigments. The resulting energy creates a map of every light and heavy metal.

We discovered extensive reworking on the image's left side. Picasso seems to have painted over the background and Stein's coat repeatedly with hasty and broad streaks. We also identified signs that he revisited her face, eventually completely shifting the angle of her gaze.

It's like a detective story: We can spy into the past and gain a better understanding of both the artist and the sitter. Many suspect it wasn't just Picasso's perfectionism that led to the many do-overs. Stein's powerful personality may have driven the many changes too.

as told to Sandra Gutierrez G.

SEASONS CHANGE.
ADAPT WITH WEATHERTECH.
FloorLiner™
CupFone®

WeatherTech's accessories always fit and protect your vehicle even as the seasons change. Secure your phone and navigate safely with CupFone, and protect your interior from the elements with FloorLiner.

MADE IN USA

WeatherTech®.com

Auto. Home. Pet. Find Your Fit.

© 2020 MacNeil IP LLC

1-800-441-6287 or 1-630-769-1500

if these stones could walk

RICHARD NORRIS, PROFESSOR OF PALEOBIOLOGY AT SCRIPPS INSTITUTION OF OCEANOGRAPHY

When we were kids, my uncle used to take my cousins and me on trips to Racetrack Playa. Geologists know the flat, dry lake bed in California's Death Valley National Park for one strange phenomenon: its slithering stones. Since the late 1940s, they've been investigating how boulders scattered across the land—some as big as compact fridges—seemingly move thousands of feet on their own. Theories abounded, from the reasonable to the absurd, but no one had ever seen the rocks in action. Death Valley, as its name implies, is inhospitable. Put aside that it's one of the hottest places on Earth, but it's also hit by severe winter storms. No one wanted to sit around and watch.

But in 2011, my cousin Jim, an engineer, came to me with an idea. He suggested setting up cameras near the stones and letting the equipment gather data. The National Park Service said we couldn't leave a trace, so we drilled into our own stones, embedded GPS trackers, and placed them, along with time-lapse cameras, near the rocks. For years, nothing moved. Then, in 2013, we got lucky.

We'd driven eight hours to the park to change the batteries in the GPS, just as we did every few months. This time, though, we discovered there'd been a huge snowstorm. The lake bed was full of water and it was freezing fast. As we walked around in the moonlight, the whole playa was hissing—the sound of ice crystallizing. But by the next morning, the sun was shining, and everything was melting. As the thin sheets of ice started to slide across the meltwater, to our astonishment, they pushed the rocks with them.

It was a head-slapping moment. Prior theories had gotten close, but we were the first people to directly observe it. And no wonder: It all happened so fast. If you got too involved in your lunch, it'd be over. Fortunately, we stayed alert, and our GPS trackers generated a ton of high-quality supporting evidence.

as told to Eleanor Cummins

BOULDER THEORIES

A HISTORY OF ROCK MOVEMENT POSTULATIONS

ALGAE FLOAT
One researcher suggested that algal film might form on the playa, making the flat surface slick enough that a prevailing breeze could scoot the rocks along.

WHIPPING WIND
Some theorists thought air currents worked on their own. If ever a hurricane-force wind swept over Southern California, it could certainly push the boulders around.

OUTSIDE FORCE
An unsubstantiated claim once held that something in Earth's magnetic field triggered the stones' sudden movement. (It makes more sense than aliens, another popular hypothesis.)

ICY PUSH
One group got close: It proposed that during a storm, ice would freeze around the stones and they'd glide across the playa. But ice can't hold that fast to individual rocks the way it can in one big sheet.

my illustrations really go viral

ALISSA ECKERT, SCIENTIFIC AND MEDICAL ILLUSTRATOR AT THE CENTERS FOR DISEASE CONTROL AND PREVENTION

When the novel coronavirus first took hold in the United States in early 2020, my colleague Dan Higgins and I were tasked with a unique job: Create a beauty shot of the microscopic public enemy number one.

We'd both previously lent our artistic expertise to emergency responses for outbreaks of Ebola, Zika, and H1N1—and the CDC's ongoing battle with antibiotic resistance. So we had practice taking microbes that were incredibly dangerous, but essentially invisible, and transforming them into bold, striking figures. You need something that's going to grab attention as people are scrolling through the news or social media.

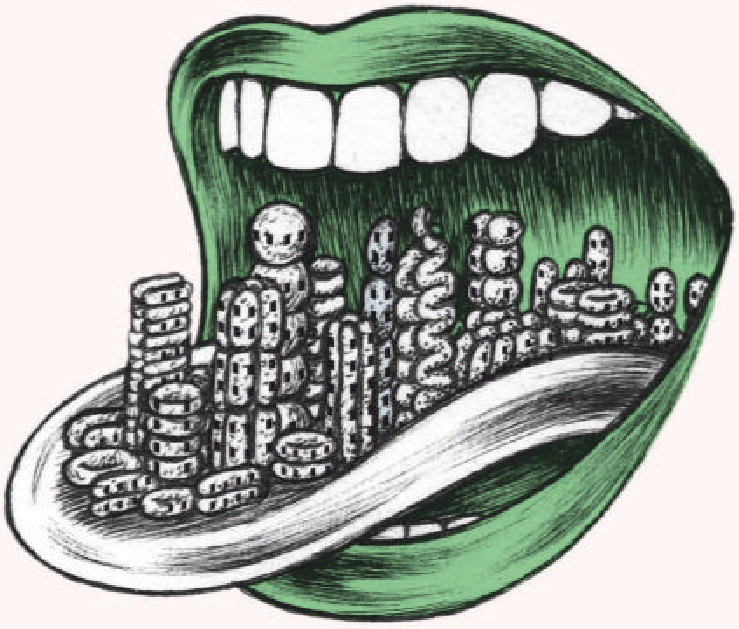
We worked with virologists to help decide what characteristics of the pathogen were important to highlight and could easily lend themselves to artistic rendering. We zeroed in on a specific component known as the S or spike protein. Copies of it rest on the outside surface of the microbe and make SARS-CoV-2, the virus that causes COVID-19, look as if it bears a crown. The proteins are also what allow the invader to gain entry and attach to human cells. We made those thorny segments red; every other color felt flat. I also gave them a rugged texture that people can imagine feeling between their fingers. I hoped this would make the virus look real and signal that it's a true enemy. We also used stark shadows, as the high contrast creates an ominous scene that inspires urgency.

The final image seems to have struck a chord. I was surprised that it has not only appeared in public health and media reports but has also inspired piñatas, cookies, and little dolls. I've even seen folks creating hairdos meant to resemble the cherry-colored spikes. We did our job: The image is cemented in people's minds.

as told to Kate Baggaley

the secrets at the tip of your tongue

JESSICA MARK WELCH, ASSOCIATE SCIENTIST AT THE MARINE BIOLOGICAL LABORATORY IN WOODS HOLE



Bacteria run the world, and even though they're all around us and seemingly crucial to the function of every single biological ecosystem, we still know little about them. Understanding how a big and diverse population of microorganisms relates to itself and its environment—particularly how each one is distributed within the space it occupies—will help us better grasp the dynamics behind complex microbial networks affecting the well-being of all living creatures.

The human mouth is one of the most densely packed bacterial hot-spots anyone's ever studied, so my colleagues and I scraped the tongues of 21 volunteers and placed the gunk onto microscope slides. Using data from the Human Microbiome Project, we identified the 17 most abundant kinds of bacteria and attached a dye that gave each one a different color when we shined a laser on them.

The resulting image resembled a city skyline, with microbial stacks jutting outward from each tongue cell. Actinomyces and Rothia—which play a key role in turning food's nitrate into nitric oxide that helps regulate blood pressure—showed up in just about every sample. The former stayed close to a cell's center while the latter resided near the edge. Now we want to figure out why they are distributed this way.

as told to Claire Maldarelli

weather is hard

BRETT ROSSIO, METEOROLOGIST AT ACCUWEATHER

The models my fellow meteorologists and I use to make forecasts can be fairly accurate. But when predicting conditions in a very specific area, things get tricky.

I understand how frustrating that can be, because I've dealt with surprise showers myself. There's one particular incident I'll never forget: It was the peak of summer in 2018, and my friends and I were on our way to a music festival near our house in State College, Pennsylvania. I had personally analyzed the weather data and was confident there would be no rain. Then, out of nowhere, big cumulonimbus clouds formed above us—the dark, extra-puffy kind that are clearly loaded with precipitation. Soon a torrential downpour drenched precisely and exclusively the area where the event was taking place. We got soaked, and my friends were not pleased.

To determine the weather, we use, among other things, a series of equations to analyze raw data, such as dew point, temperature, wind, and barometric pressure. But that process neglects variables that are difficult to quantify, like the amount of moisture coming off the surface of the Earth at any given time in a specific location. Too much evaporation can sometimes turn a cloudy afternoon into a thunderstorm (though I still think other factors triggered the rain that day). I've learned even the best models are just tools; sometimes you have to pop your head out the window and look up.

as told to Sandra Gutierrez G.

IRIS™ Camera

- Overhead Cameras Provide Live Views
- Drag and Drop Artwork on Screen
- Easy Setup and Positioning
- Quick Onscreen Camera Layout

EpilogLaser

888.437.4564 | SALES@EPILOGLASER.COM | EPILOGLASER.COM/POPSCI

FusionPro
EpilogLaser.com

ADVERTISEMENT

Choose Life
Grow Young with HGH

From the landmark book Grow Young with HGH comes the most powerful, over-the-counter health supplement in the history of man. Human growth hormone was first discovered in 1920 and has long been thought by the medical community to be necessary only to stimulate the body to full adult size and therefore unnecessary past the age of 20. Recent studies, however, have overturned this notion completely, discovering instead that the natural decline of Human Growth Hormone (HGH), from ages 21 to 61 (the average age at which there is only a trace left in the body) and is the main reason why the the body ages and fails to regenerate itself to its 25 year-old biological age.

Like a picked flower cut from the source, we gradually wilt physically and mentally and become vulnerable to a host of degenerative diseases, that we simply weren't susceptible to in our early adult years.

Modern medical science now regards aging as a disease that is treatable and preventable and that "aging", the disease, is actually acompilation of various diseases and pathologies, from everything, like a rise in blood glucose and pressure to diabetes, skin wrinkling and so on. All of these aging symptoms can be stopped and rolled back by maintaining Growth Hormone levels in the blood at the same levels HGH existed in the blood when we were 25 years old.

There is a receptor site in almost every cell in the human body for HGH, so its regenerative and healing effects are very comprehensive.

Growth Hormone first synthesized in 1985 under the Reagan Orphan drug act, to treat dwarfism, was quickly recognized to stop aging in its tracks and reverse it to a remarkable degree. Since then, only the lucky and the rich have had access to it at the cost of $10,000 US per year.

The next big breakthrough was to come in 1997 when a group of doctors and scientists, developed an all-natural source product which would cause your own natural HGH to be released again and do all the remarkable things it did for you in your 20's. Now available to every adult for about the price of a coffee and donut a day.

GHR now available in America, just in time for the aging Baby Boomers and everyone else from age 30 to 90 who doesn't want to age rapidly but would rather stay young, beautiful and healthy all of the time.

New! Doctor Recommended

The Reverse Aging Miracle

RELEASE YOUR OWN GROWTH HORMONE AND ENJOY:

- Improved sleep & emotional stability
- Increased energy & exercise endurance
- Loss of body fat
- Increased bone density
- Improved memory & mental alertness
- Increased muscle strength & size
- Reverse baldness & color restored
- **Regenerates Immune System**
- Strengthened heart muscle
- Controlled cholesterol
- **Normalizes blood pressure**
- Controlled mood swings
- Wrinkle disappearance
- Reverse many degenerative disease symptoms
- Heightened five senses awareness
- Increased skin thickness & texture

All Natural Formula

This program will make a radical difference in your health, appearance and outlook. In fact we are so confident of the difference GHR can make in your life we offer a 100% refund on unopened containers.

A Product of Global Health Products

1-877-849-4777

www.biehealth.us

GHR

BIE Health Products
3840 East Robinson Road
Box 139
Amherst, NY14228

DIV 2037839 ON

The new HGH releasers are winning converts from the synthetic HGH users as well, since GHR is just as effective, is oral instead of self-injectable and is very affordable.

GHR is a natural releaser, has no known side effects, unlike the synthetic version and has no known drug interactions. Progressive doctors admit that this is the direction medicine is seeking to go, to get the body to heal itself instead of employing drugs. GHR is truly a revolutionary paradigm shift in medicine and, like any modern leap frog advance, many others will be left in the dust holding their limited, or useless drugs and remedies.

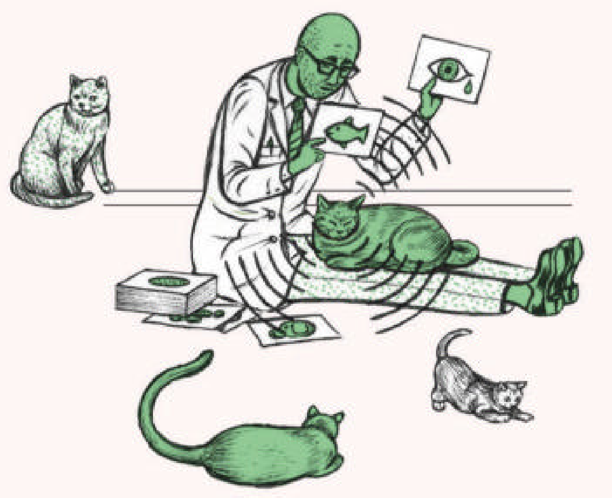
It is now thought that HGH is so comprehensive in its healing and regenerative powers that it is today, where the computer industry was twenty years ago, that it will displace so many prescription and non-prescription drugs and health remedies that it is staggering to think of.

The president of BIE Health Products stated in a recent interview, I've been waiting for these products since the 70's. We knew they would come, if only we could stay healthy and live long enough to see them! If you want to stay on top of your game, physically and mentally as you age, this product is a boon, especially for the highly skilled professionals who have made large investments in their education, and experience. Also with the failure of Congress to honor our seniors with pharmaceutical coverage policy, it's more important than ever to take pro-active steps to safeguard your health. Continued use of GHR will make a radical difference in your health, HGH is particularly helpful to the elderly who, given a choice, would rather stay independent in their own home, strong, healthy and alert enough to manage their own affairs, exercise and stay involved in their communities. Frank, age 85, walks two miles a day, plays golf, belongs to a dance club for seniors, had a girl friend again and doesn't need Viagara, passed his drivers test and is hardly ever home when we call - GHR delivers.

HGH is known to relieve symptoms of Asthma, Angina, Chronic Fatigue, Constipation, Lower back pain and Sciatica, Cataracts and Macular Degeneration, Menopause, Fibromyalgia, Regular and Diabetic Neuropathy, Hepatitis, helps Kidney Dialysis and Heart and Stroke recovery.

For more information or to
order call 877-849-4777
www.biehealth.us
©copyright 2000

CODE PSC



purrr speculation

CARLO SIRACUSA, PROFESSOR OF CLINICAL ANIMAL BEHAVIOR AT THE UNIVERSITY OF PENNSYLVANIA

Domestic cats communicate to other felines with gestures like pupil dilation and skin twitching. Because we humans are bad at decoding this subtle language, our pets have learned to use other types of cues with us. Purring falls in that category, but after about nine thousand years living together, we're still not sure what it means.

It isn't necessarily a sign of contentment, as most people think. Our furry companions will purr at the vet, but they're not exactly happy to be squeezed and examined. On the contrary, they may be saying, "I'm vulnerable, help me." We call this an et-epimeletic behavior, which animals use to demand care and attention—oftentimes from a mother, but possibly from their human.

There are other theories about this delicate rumble. One is that its frequency promotes soft tissue and bone healing in injured felines. Others suggest this characteristic hum is a recent evolutionary adaptation in house cats, who might be using the relaxing effect those low vibrations have on their owners to encourage the human guardians to care for and protect them.

Unfortunately, there's no data backing any hypothesis over another, and a lot depends on personality, too. With my cat, Elsa, you never know: She might bite or swipe—even shortly after purring.

as told to Marion Renault

DANIEL STEIGER

Abalone Hummingbird Pendant & Earrings Collection

- Graceful Hummingbird Design
- Solid 925 Sterling Silver
- Abalone Mother Of Pearl
- Complimentary 22" Chain
- 1.57" Length

Now with matching Abalone Hummingbird Earrings

Natural Shell Abalone

The hummingbird is a traditional symbol of love and beauty.

Suspended in mid-flight, with a rainbow of iridescence in wave-like patterns, outstanding shimmering Abalone decorates her body and wing.

Each unique, one of a kind piece of Abalone Shell has been molded into a sterling silver pendant.

Traditionally Abalone Shell is said to induce feelings of peace, compassion, and love. It has a lovely warm, gentle cosmic vibration.

Considered perfect in times of tough emotional issues, soothing the nerves, and encouraging calmness. Originally priced at $249. Take advantage of this truly spectacular introductory offer.

With your promo code below order today and pay just $99 plus S&H.

Hurry and order today using the information below.

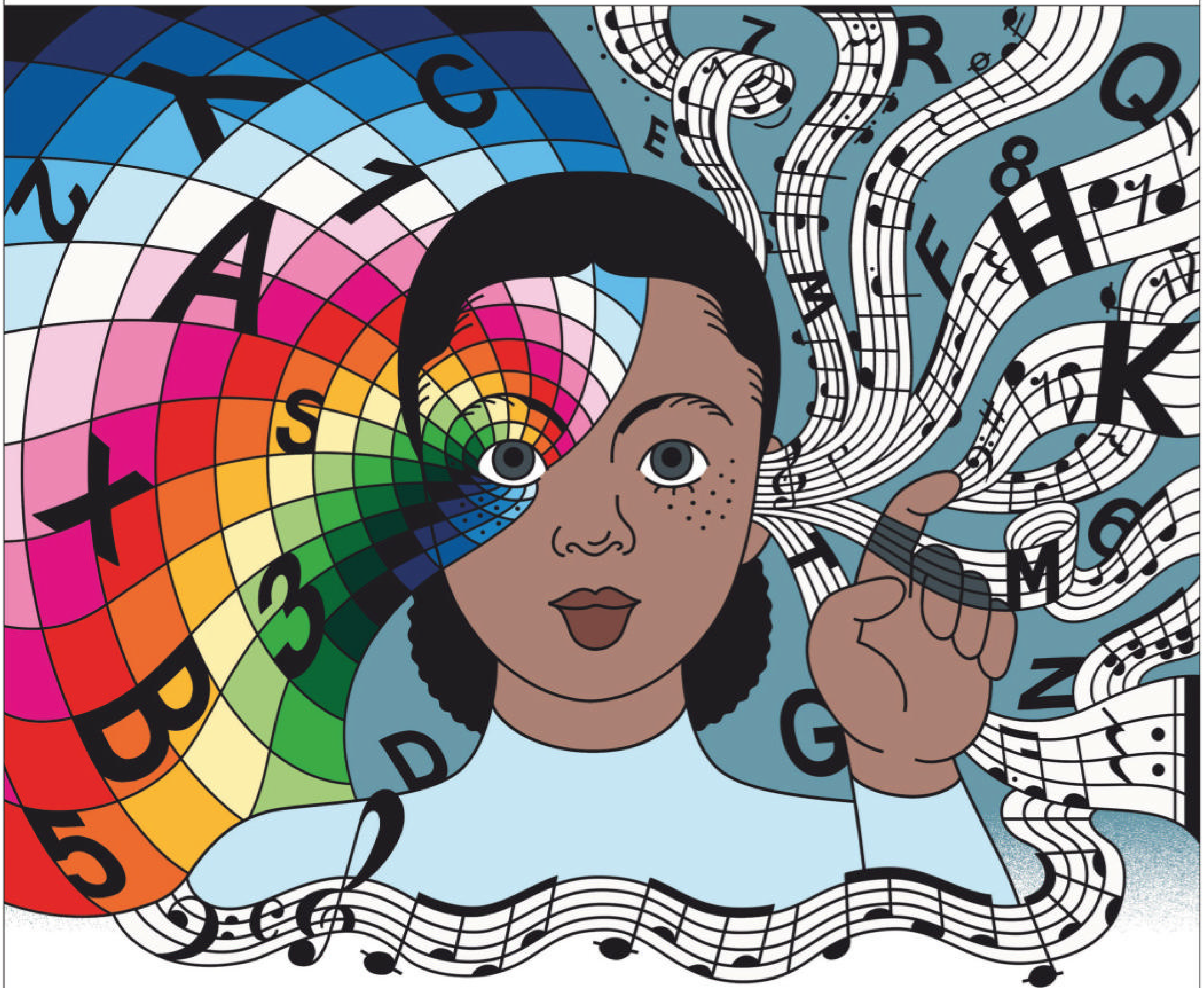
Original Price Without Promo Code ~~$249~~
With Promo Code $99 plus s&h
Abalone Hummingbird Pendant $99 plus s&h / Abalone Hummingbird Earrings $99 plus s&h
Extra Saving: Abalone Hummingbird Collection $169 plus s&h (save additional $29)

ORDER NOW TOLL FREE 24/7 ON 1-800 733 8463
AND QUOTE PROMO CODE: PS29HB
Or order online at timepiecesusa.com/ps29hb
and enter promo code PS29HB

Timepieces International Inc, 10701 NW 140th Street, Suite 1,
Hialeah Gardens, Florida, 33018

HEAD TRIP

ILLUSTRATIONS BY **TOMI UM**



yes, people can taste names and hear colors

BY *MARION RENAULT*

FOR A SMALL GROUP OF PEOPLE, sensations entangle themselves in baffling ways. The written numeral 2 might evoke a flash of purple; an audible C sharp note could conjure a finger prick. Some with this condition, called synesthesia, even taste spoken words: The name Sam, for example, might elicit a sweet flavor.

How exactly some people "feel" smells or "taste" names is still generally unclear. There's no gold standard test to diagnose the condition, which only adds to the mystery. University of Michigan cognitive psychologist David Brang says he gets emails all the time from folks asking if their peculiar sensations are the result of such swapping. "It's a mixing of the senses," he says, making the disorder "very difficult to reverse engineer."

The current theory posits that synesthetes' brains have extra connections. When you see a word, your retina and optic nerve send that information to the visual cortex, which creates the image you see. Then your noggin's face- and color-recognition unit, the fusiform gyrus, puts it into context. Extra connections there might simultaneously send signals to, say, both the color- and word-focused regions. Those extra pathways can pigment terms, weaponize musical notes, or even ruin a first date with a rather putrid-tasting name.

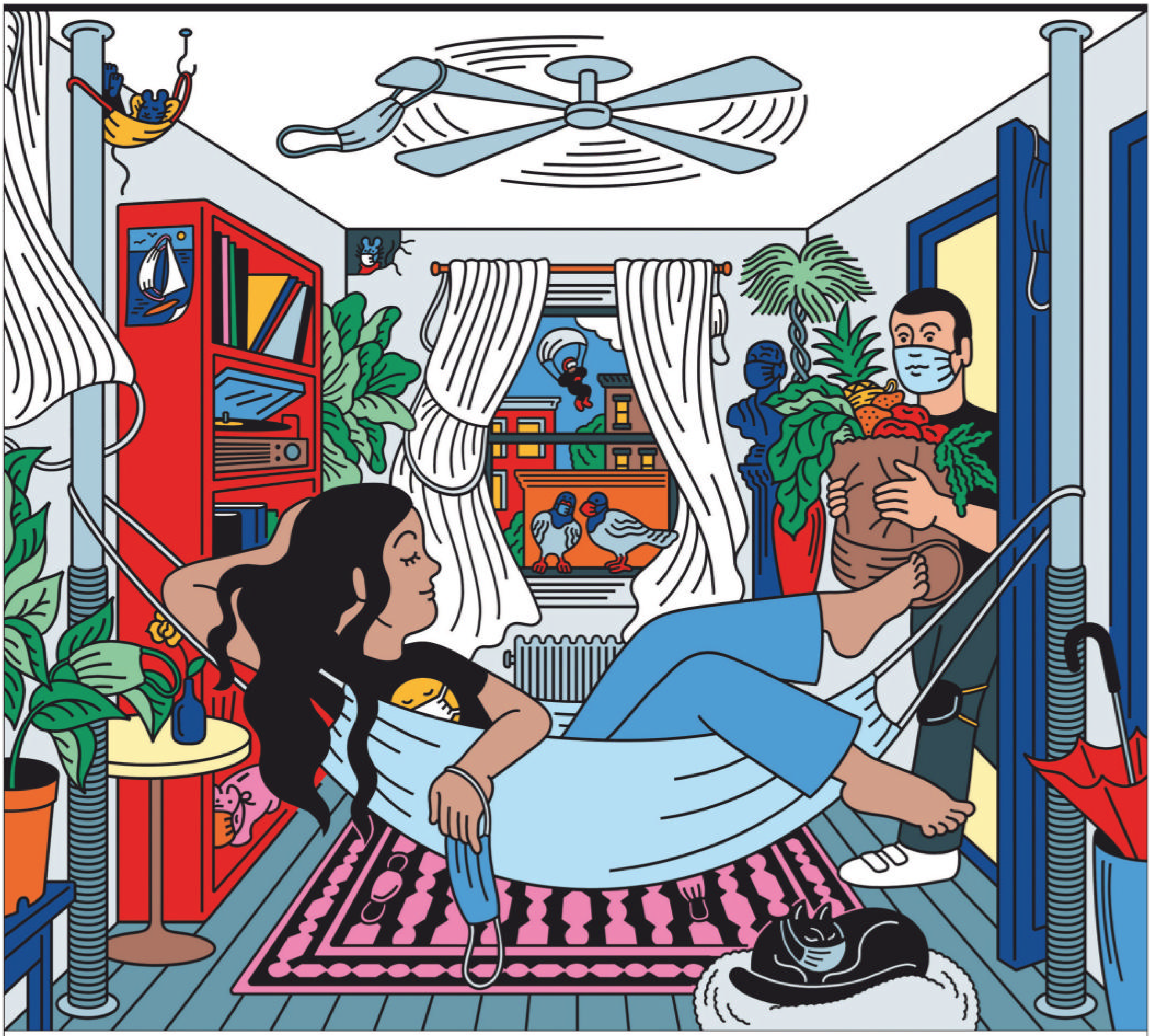
does free will exist?

BY *SARA KILEY WATSON*

HERE'S A MIND-BENDING question: Are you reading this because you definitively chose to or because you were destined to?

Philosophers have pondered free will's existence for millennia, and neuroscientists began to consider whether humans go about their lives of their own accord in the 1960s. But it wasn't until a pivotal 1983 study that anyone had any hard evidence in either direction; researchers asked participants to consciously decide to move a finger prior to raising it and recorded their brain activity with an EEG. Surprisingly, before subjects chose to move, their grey matter lit up, suggesting noggins make determinations before we're aware of them. Over the years, the finding has been met with scrutiny, as the actual reason for those EEG spikes is still unclear.

Modern investigators like Uri Maoz, a computational neuroscientist at Chapman University, are instead tackling the quandary with data. If a supercomputer knows everything about us (from life goals to favorite ice cream) and every decision we make (including instinctual ones happening since birth) influences the next, then a machine could spit out the most likely choice we'd make in any situation. Maoz and others currently study whether there is any chance you'd pick something totally different from what a supercomputer might predict. But in the case of this article, since you've nearly finished, it's more or less a moot point.



try to spot all the masks in this picture

YOU PROBABLY OVERLOOK THINGS RIGHT IN FRONT OF YOU EVERY SINGLE DAY

BY *JILLIAN MOCK*

HAVING TROUBLE FINDING EVERY FACE covering? There's a reason tasks like this are challenging for even experienced puzzle sleuths: We don't see everything in our field of view. In fact, our brains forbid it.

Our minds can only focus on so much at once, says Susana Martinez-Conde, a neuroscientist at SUNY Downstate Medical Center in New York. Neurons in our visual cortices have limited bandwidth. If they attempted to take in everything, we would struggle to pick out life-or-death details. So the brain directs our vision, filtering out irrelevant objects. If we're crossing the street, it sends signals to tune into a car speeding toward us as opposed to, say, a bluebird or a friendly neighbor out for a stroll. We might miss some things, but at least we'll live to tell the tale.

To crack the puzzle above, focus your attention on one small section at a time—otherwise your noggin will lock in on the biggest parts of the picture and blur out everything else. (The answers are on page 106.)

HARBOR FREIGHT
QUALITY TOOLS AT RIDICULOUSLY LOW PRICES

Shop When You Need To Online & In-Store

SUPER COUPON

3-Ply Disposable Face Masks 10 Masks per Pack ★★★★½ (1464)

Less Than 40¢ Per Mask

$3.99 ~~$5.99~~

NEW

Save 33%

While Supplies Last

Non-medical.

Use Online & In-Store

ITEM 57593

34302174 LIMIT 4 - Exp. 11/13/20*

SUPER COUPON

McGRAW ★★★★½ (682)

20 Gallon, 135 PSI Oil-Lube Air Compressor

McGRAW
2x LIFE
25% QUIETER
27% MORE RUN TIME

$164.99 ~~$189.99~~

Save $85

Compare to Porter-Cable 118903799 $249.99

ITEM 56241/64857 shown

Use Online & In-Store

78964666 LIMIT 1 - Exp. 11/13/20*

WOW SUPER COUPON — SAVE 88%

★★★★★ (6220)

Grant's **12" x 12" Microfiber Cleaning Cloths Pack of 4**

WOW! **69¢** ~~$2.89~~

Compare to ProElite AZCDAB $5.99

LIMIT 3

Use Online & In-Store

ITEM 63358/63925 57162/63363 shown

78966920 Exp. 11/13/20*

SUPER COUPON

20% OFF

ANY SINGLE ITEM*

Use Online & In-Store

78961546

Limit 1 coupon per customer per day. Save 20% on any 1 item purchased. *Cannot be used with other discount, coupon or any of the following items or brands: Inside Track Club membership, Extended Service Plan, gift card, open box item, 3 day Parking Lot Sale item, compressors, floor jacks, power stations, safes, storage cabinets, chests or carts, trailers, welders, Admiral, Ames, Atlas, Bauer, Central Machinery, Cobra, CoverPro, Daytona, Diamondback, Earthquake, Fischer, Hercules, Icon, Jupiter, Lynxx, Poulan, Predator, Tailgator, Viking, Vulcan, Zurich. Not valid on prior purchases. Non-transferable. Original coupon must be presented. Valid through 11/13/20.

SUPER COUPON

TAILGATOR ★★★★½ (1260)

900w Max. Starting 2 Cycle Gas Powered Generator

$109.99 ~~$124.99~~

Save $16

Compare to PowerSmart PS50 $126.10

ITEM 63024/63025 shown

Use Online & In-Store

78967689 LIMIT 1 - Exp. 11/13/20*

SUPER COUPON

7 ft. 4" x 9 ft. 6" All Purpose/ Weather Resistant Tarp ★★★★½ (2301)

$2.99 ~~$4.99~~

Save 65%

Compare to Blue Hawk BG8X10-Y $8.78

ITEM 69115/69121/69129 69137/69249/877 shown

Use Online & In-Store

78968081 LIMIT 4 - Exp. 11/13/20*

SUPER COUPON

200 Lumen LED Super Bright Flip Light

★★★★★ (5995)

$1.99 ~~$3.99~~

Save 60%

Compare to Promier SW-SWITCH-12/24 $4.99

ITEM 64723/64189 63922 shown

Use Online & In-Store

78968415 LIMIT 4 - Exp. 11/13/20*

SUPER COUPON

U.S. GENERAL ★★★★★ (1197)

30", 4 Drawer Tech Cart

YOUR CHOICE OF 6 COLORS

$149.99 ~~$1099.99~~

Save $730

Side tray sold separately.

Compare to Snap-on Blue-Point KRBC10TBPC $880

ITEM 56387, 56393, 64096, 56392, 56386, 56394

Use Online & In-Store

78969850 LIMIT 1 - Exp. 11/13/20*

SUPER COUPON

Heavy Duty Foldable Aluminum Sports Chairs ★★★★★ (5138)

YOUR CHOICE OF COLOR

$19.99 ~~$29.99~~

Green ITEM 63066/62314 shown

Blue ITEM 56719

Save 50%

Compare to Coleman 635394 $39.99

Use Online & In-Store

78975986 LIMIT 3 - Exp. 11/13/20*

SUPER COUPON

COVERPRO ★★★★ (1890)

10 ft. x 17 ft. Portable Garage

Save $120

$169.99 ~~$199.99~~

Compare to Shelter Logic 76377 $290.75

ITEM 62859/63055/62860 shown

Use Online & In-Store

78977969 LIMIT 1 - Exp. 11/13/20*

SUPER COUPON

WARRIOR ★★★★½ (5034)

29 Piece Titanium Drill Bit Set

$10.99 ~~$18.99~~

Save 83%

Compare to Dewalt DW1369 $68.14

ITEM 5889/62281 61637 shown

Use Online & In-Store

78978176 LIMIT 3 - Exp. 11/13/20*

SUPER COUPON

PORTLAND ★★★★½ (7226)

7 AMP Electric Pole Saw 9.5" Bar

6 FT. to 8 FT. 10"

$59.99 ~~$79.99~~

Save $39

ITEM 56808/68862 63190/62896 shown

Compare to Worx WG309 $99.98

Use Online & In-Store

78981473 LIMIT 1 - Exp. 11/13/20*

SUPER COUPON

PITTSBURGH AUTOMOTIVE ★★★★½ (2880)

300 lb. Capacity ATV/Lawn Mower Lift

$74.99 ~~$99.99~~

Save $46

ITEM 60395/62325/62493/61523 shown

Compare to Max Load 38028 $121.47

Use Online & In-Store

78982865 LIMIT 1 - Exp. 11/13/20*

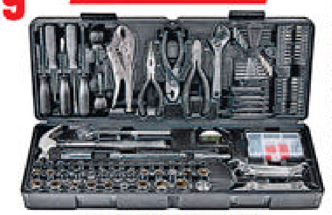
SUPER COUPON

PITTSBURGH ★★★★½ (3872)

130 Piece Tool Kit with Case

$29.99 ~~$39.99~~

LIFETIME WARRANTY



Save 54%

SAE AND METRIC

Compare to Anvil A137HOS $66.39

ITEM 64263/68998 63248/64080/63091 shown

Use Online & In-Store

78984068 LIMIT 3 - Exp. 11/13/20*

SUPER COUPON

drillmaster ★★★★½ (6382)

4-1/2" Angle Grinder

$9.99 ~~$14.99~~

Save 50%

Compare to Ironton 61451 $19.99

ITEM 69645/60625 shown

Use Online & In-Store

78984092 LIMIT 4 - Exp. 11/13/20*

SUPER COUPON

HaulMaster ★★★★★ (5011)

18" Working Platform Step Stool

$19.99 ~~$29.99~~

Save 50%

Compare to Neocraft 60635 $39.99

ITEM 62515/66911 shown

Use Online & In-Store

78984707 LIMIT 3 - Exp. 11/13/20*

SUPER COUPON

CEN-TECH ★★★★½ (3908)

Automatic Battery Float Charger

$4.99 ~~$9.99~~

Save 83%

Compare to Schumacher Electric SC1 $30.41

ITEM 64284/69955 42292 shown

Use Online & In-Store

78985293 LIMIT 4 - Exp. 11/13/20*

SUPER COUPON

PITTSBURGH #1 SELLING JACKS IN AMERICA ★★★★★ (1716)

Rapid Pump® 1.5 Ton Lightweight Aluminum Floor Jack

ASME PASE COMPLIANT
PITTSBURGH

$59.99 ~~$79.99~~

Save $91

Compare to K Tool KTI63094 $151.42

ITEM 64552/64832 64980/64545 shown

Use Online & In-Store

78985702 LIMIT 1 - Exp. 11/13/20*

SUPER COUPON

HaulMaster ★★★★★ (1296)

3/8" x 14 ft., Grade 43 Towing Chain

Save 69%

$19.99 ~~$39.99~~

Compare to Mibro 426920 $64.99

ITEM 60658/97711 shown

Use Online & In-Store

78986928 LIMIT 4 - Exp. 11/13/20*

SUPER COUPON

PREDATOR ★★★★★ (3554)

6.5 HP (212 CC) OHV Horizontal Shaft Gas Engine

$99.99 ~~$119.99~~

Save $230

Compare to Honda GX200UT2QX2 $329.99

ITEM 60363/69730 shown

ITEM 69727/68121 CALIFORNIA ONLY

Use Online & In-Store

78987240 LIMIT 1 - Exp. 11/13/20*

1,000+ Stores Nationwide • HarborFreight.com

*Original coupon only. No use on prior purchases after 30 days from original purchase or without original receipt. Valid through 11/13/20.

Pricing, promotions, and availability may vary by location and at www.harborfreight.com and are subject to change without notice. We reserve the right to limit quantities. "Compare to" advertised price means that the specified comparison, which is an item with the same or similar function, was advertised for sale at or above the "Compare to" price by another national retailer in the U.S. within the past 90 days. Prices advertised by others may vary by location. No other meaning of "Compare to" should be implied. Although we make every effort to assure that our prices and products are advertised as accurately as possible, we are only human and in the event an error is made, we reserve the right to correct it.

SATISFACTION GUARANTEED
FAST-ACTING LIQUID SOFT-GELS
LIBIDO-MAX
POWER EXTENDING FORMULA
Doctor Developed Male Enhancement
3-PART PHYSICAL RESPONSE:
ENHANCED VITALITY
HEALTHY BLOOD FLOW
BOOST PLEASURE
75 FAST-ACTING LIQUID SOFT-GELS
DIETARY SUPPLEMENT

WORKS FOR YOU...
OR YOUR MONEY BACK!

Available for purchase with coupon in fine stores everywhere or online at:
www.appliednutrition.com
Enter Coupon Code: 014316

Kmart Walgreens CVS/pharmacy Kroger Rite Aid Super Centers meijer

LIBIDO-MAX for MEN
75 Count ONLY
SAVE $3
EXPIRES 11/30/20 MANUFACTURERS COUPON

Consumer: Redeemable at retail locations only. Not valid for online or mail-order purchases. Retailer: Irwin Naturals will reimburse you for the face value plus 8 (cents) handling provided it is redeemed by a consumer at the time of purchase on the brand specified. Coupons not properly redeemed will be void and held. Reproduction by any party by any means is expressly prohibited. Any other use constitutes fraud. Irwin Naturals reserves the right to deny reimbursement (due to misredemption activity) and/or request proof of purchase for coupon(s) submitted. Mail to: CMS Dept. 10363, Irwin Naturals, 1 Fawcett Drive, Del Rio, TX 78840. Cash value: .001 (cents). Void where taxed or restricted. ONE COUPON PER PURCHASE. Not valid for mail order/websites. Retail only.

0710363-014316

These statements have not been evaluated by the Food & Drug Administration. This product is not intended to diagnose, treat, cure or prevent any disease.

why sports fans cling to superstitions

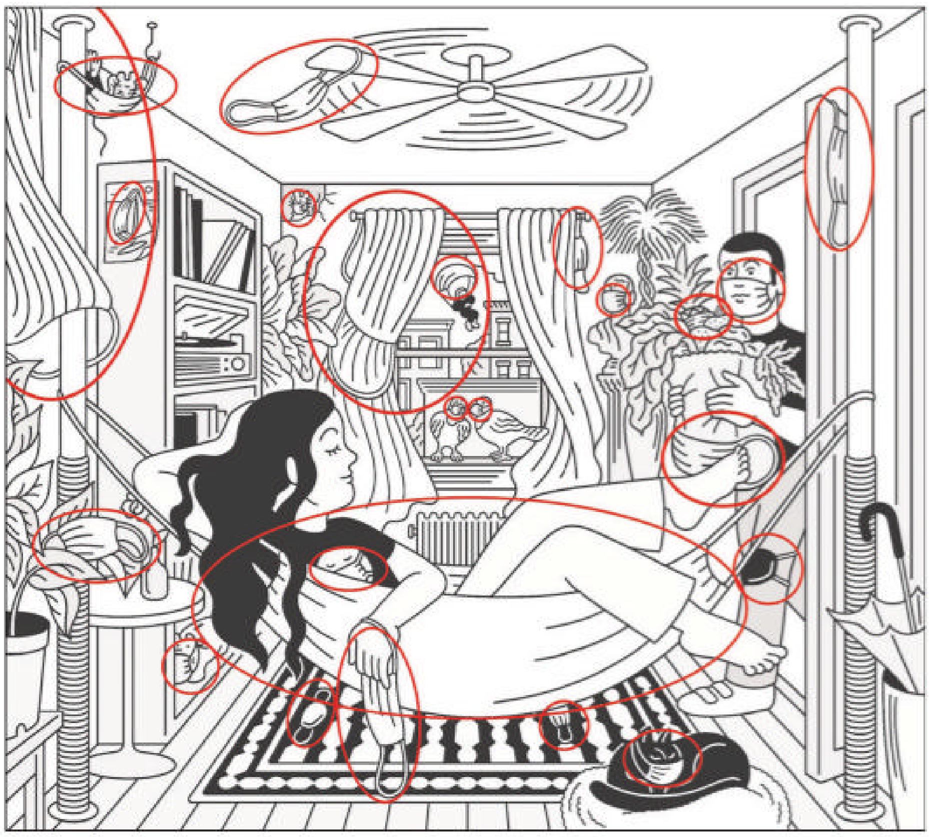
BY *MADDIE BENDER*

▶ **WITCHES WOULD FEEL** right at home within the fan base of a sports team, where curses, hexes, and charms abound. As if compelled by magic, superstitious diehards have worn inside-out good-luck hats called rally caps, planted team memorabilia on Mount Everest's peak, and displayed butchered goats on stadium grounds—all because they believe it'll help their treasured team win. These rituals don't influence the outcome of the match, so why do they exist?

Such actions often arise from a place of helplessness, according to Murray State University sports psychologist Daniel Wann. Superstitious practices put fans' minds at ease because they make them feel as if they have some control over the game. There's also a bit of peer pressure involved. Studies show that being part of a team's hype squad offers a sense of belonging and togetherness, which may be behind cheerers' decisions to take part in unusual routines. Plus, when a team wins a nail-biter, you can't help but wonder if your rally cap had something to do with it.

GLENN ORZEPOWSKI

ANSWER KEY FOR PAGE 104. THERE ARE 24 MASKS.



(CONTINUED FROM PAGE 45)

effort in midspring. In March 2020, the COVID-19 pandemic forced the facility to shut down on-site work aside from critical maintenance. Some of the scientists stayed in town, since travel—particularly internationally—seemed dicey, and Lead (population 3,021) was a pleasant enough place to be stranded for however long they would hang in this virus-induced limbo.

There's still plenty to do aboveground, plenty of calibrations to perfect. No matter when they start, it'll take five years of WIMP sniffing to gather enough data to know if the particle is in the LZ's detection range. And besides, as project coordinator Lesko points out, all those months of double shifts had paid off: They'd nearly completed assembly down on 4850, and the project was in a stable and safe spot. Few places are more secure during a pandemic than one close to a mile underground.

Still, like the rest of us, they wonder when this all might be over: when they can get fully back to the experiment, and if, once they do—with the LZ tank sealed and detector arrays watchfully waiting—they'll find anything at all. None of the nearly one dozen prior attempts to nab a glimmer of a WIMP over the past three decades have worked. Yet team members like Fruth, the photon detector specialist, are sanguine about the possibility of their life's work netting nothing. "Knowing that it's not something is still worth something," she says. When you aren't sure exactly what a WIMP is, there's value in finding out what it isn't.

Living with uncertainty and pondering the unknown is a comfortable space for them to be in, because that's what scientists do—especially physicists on this particular ongoing hunt. Fruth likens dark matter to the unfilled portion of a map, the "here be monsters" bits. "We draw this line," she says, "and we say, 'Look, we don't know anything beyond this line.' And then we push a little farther, and know a little more. And the line moves, and we move with it."

(CONTINUED FROM PAGE 93)

the credibility, educate the users, the businesspeople—the nature of it depends on consensus," he says.

When Stephane Germain conceived of GHGSat, it took more than 100 cold calls to energy companies to satisfy himself that his venture could find customers. Now, under pressure from investors, Shell has tied its executive compensation to its emissions reductions, aiming for 20 percent in 15 years, and has hired GHGSat. BP has promised to add methane-measuring devices at its major processing sites in three years and halve its emissions per volume of product. Activists who own stock in ExxonMobil, Chevron, and others have become increasingly ornery about greenhouse gases, so they may win more concessions from executives on environmental metrics. Saudi Aramco, the national oil company that went public in 2019, may also begin to feel pressure from shareholders.

Hirst, the atmospheric monitoring expert, believes that these moves have at least partly been motivated by the coming swarm of orbiters sniffing out leaks. "Within a few years, they will show how bad these sources are," he says. "As more sensitive satellites are launched, it'll become more common to see sources that need remediation."

When everyone can look at a map of the world and zoom in to see where methane is coming from, and when regulators can quantify the amounts and start charging for them, polluters might decide business as usual is no longer a viable option.

V1 for 2025 is here!

Meet Valentine One® Generation 2

"It's about range superiority. I told my engineers, 'We want the best radar-finding engine this side of the military.'

For civilian users, V1 Gen2 is a break-through on range."

— Mike Valentine

All-new circuitry with SAW D²L

Radar ahead | Radar beside | Radar behind

www.valentine1.com

Valentine One Generation 2 Radar Locator - $499
Carrying Case - $35 | SAVVY® - $69
Plus Shipping | Ohio residents add sales tax

30-Day Money Back Guarantee

Valentine One Generation 2 and SAVVY are registered trademarks of Valentine Research, Inc. ©2020 VRI

1-800-331-3030

Valentine One® Radar Locator

Valentine Research, Inc.
Department No. YGC
10280 Alliance Road
Cincinnati, Ohio 45242
Ph 513-984-8900
Fx 513-984-8976

PROFESSIONAL POWER DR DONE RIGHT

When you need it done right, do it with DR®.

FORGET THE RAKE!

World's Most Powerful Leaf Vacuum!

Tow-Behind

- Rated #1 in vacuum power.
- Huge capacity, up to 321 gallons!
- Stores flat in minutes.
- Easy, 1-handed dumping!
- Cart bed doubles as an all-purpose utility trailer.

Walk-Behind

- Easy on/off collector bags hold up to 8 bushels!
- Perfect for landscaped areas and smaller properties.

NEWLY REDESIGNED with More Power and Capacity!

DRleafvac.com

1B47AA © 2020

For the BIG JOBS, bring on the POWER of

DR® Chippers and Shredders!

CHIP

SHRED

Seven models to choose from!

POWER. Engines up to 13.5 HP for the rigors of continuous wood chipping.

CAPACITY. Chip branches up to 5.75" in diameter and shred cuttings up to 1.5" thick.

SELECTION. Models for yard, farm, and ranch—including PTO and towable units.

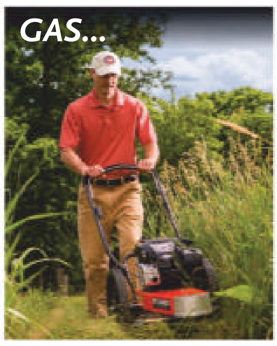
DRchipper.com

1B47AB © 2020

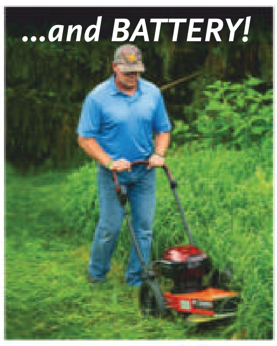
Trim and Mow the EASY Way with a

DR® Trimmer Mower!

GAS...



...and BATTERY!



5X THE POWER of a hand-held trimmer without the back strain!

THICKEST, LONGEST-LASTING cord (up to 255 mil) takes seconds to change!

10 MODELS including Self-Propelled, Tow-Behind (for ATV) and PTO!

The ORIGINAL Trimmer on Wheels!

DRtrimmers.com

1B47AC © 2020

FREE SHIPPING	1 YEAR TRIAL	EASY FINANCING

SOME LIMITATIONS APPLY. GO ONLINE OR CALL FOR DETAILS.

USA ENGINEERED & BUILT*

Go Online or Call for FREE Info Kit!

Includes product specifications and factory-direct offers.

TOLL FREE **800-487-1379**

* Assembled in the USA using domestic and foreign parts.

SquirrelBuster® **PLUS**

VOTED BEST BY POPULAR SCIENCE

www.bromebirdcare.com

INFO 1-800-856-5685

Sharpen your skills | Find us on

AN EDGE ABOVE THE REST.

The legendary Lansky Controlled-Angle System ensures that your knife edge is sharpened to the exact bevel you specify.

Learn more at lansky.com

LANSKY® SHARPENERS

Bad to the Bone

Full tang stainless steel blade with natural bone handle —now ONLY $79!

If you're on the hunt for a knife that combines impeccable craftsmanship with a sense of wonder, the **$79 *Huntsman Blade*** is the trophy you're looking for.

The blade is full tang, meaning it doesn't stop at the handle but extends to the length of the grip for the ultimate in strength. The blade is made from 420 surgical steel, famed for its sharpness and its resistance to corrosion.

The handle is made from genuine natural bone, and features decorative wood spacers and a hand-carved motif of two overlapping feathers— a reminder for you to respect and connect with the natural world.

This fusion of substance and style can garner a high price tag out in the marketplace. In fact, we found full tang, stainless steel blades with bone handles in excess of $2,000. Well, that won't cut it around here. We have mastered the hunt for the best deal, and in turn pass the spoils on to our customers.

But we don't stop there. While supplies last, we'll include a pair of $99 8x21 power compact binoculars *and* a genuine leather sheath **FREE** when you purchase the ***Huntsman Blade***.

Your satisfaction is 100% guaranteed. Feel the knife in your hands, wear it on your hip, inspect the impeccable craftsmanship. If you don't feel like we cut you a fair deal, send it back within 30 days for a complete refund of the item price.

Limited Reserves. A deal like this won't last long. We have only 1120 ***Huntsman Blades*** for this ad only. Don't let this beauty slip through your fingers. Call today!

EXCLUSIVE FREE Stauer® 8x21 Compact Binoculars -a $99 value- with purchase of Huntsman Blade

★★★★★

"The feel of this knife is unbelievable… this is an incredibly fine instrument."
— H., Arvada, CO

Huntsman Blade ~~$249~~*

Offer Code Price Only $79 + S&P

1-800-333-2045

Your Insider Offer Code: HUK253-01

You must use the insider offer code to get our special price.

Stauer® 14101 Southcross Drive W., Ste 155, Dept. HUK253-01
Burnsville, Minnesota 55337 www.stauer.com

**Discount is only for customers who use the offer code versus the listed original Stauer.com price.*

Not shown actual size.

California residents please call 1-800-333-2045 regarding Proposition 65 regulations before purchasing this product.

ACCREDITED BUSINESS BBB Rating of A+

- **12" overall length; 6 ½" stainless steel full tang blade • Genuine bone handle with brass hand guard & bolsters • Includes genuine leather sheath**

Stauer… *Afford the Extraordinary.*®

Stauer
3 ATM WATER RESISTANT
24

Only $29!

You would be hard pressed to find a timepiece of this outstanding quality and precision at this price.

It's Enough to Make You Blue in the Face

Time to take a stand against overpriced watches with the Stauer Urban Blue, **now only $29**

You need a new watch…the one you are wearing was made when Nixon was in office, but extravagantly-priced watches that add zeros just because of a high falootin' name are an insult to your logic. Why shell out big money so some foreign company can sponsor another yacht race? It's time to put an end to such madness. It's absolutely possible to have the highest quality, precision classic timepiece without the high and mighty price tag. Case in point: The Stauer *Urban Blue.*

Packed with high-end watch performance and style, minus the high-end price tag. It's everything a high-end watch should be: Sturdy stainless steel and genuine leather construction. Precision timing that's accurate to four seconds a day—that's more precise than a 27-jewel automatic watch priced at over $6,000. And, good looking— with simple, clean lines and a striking metallic blue face.

"Blue watches are one of the growing style trends seen in the watch world in the past few years"—WATCHTIME®

Your great escape from the over-priced watch craze. At Stauer, we go directly to the source (cutting out the middleman), and engineer our own watch designs. This means we can offer a top quality timepiece that happens to only cost the same as two well-made cocktails at your favorite bar. So, while we're busy revolutionizing the watch industry to bring you more real value, you can take your own stand against overpriced watches with the *Urban Blue.*

Your satisfaction is 100% guaranteed. Wear the *Urban Blue for* 30 days. If you're not convinced that you achieved excellence for less, send it back for a refund of the item price. The *Urban Blue* is one of our fastest sellers. Take a stand against overpriced watches in impeccable style. **Limited to the first 1900 responders to this ad only.** Don't miss out...call today!

Stauer Urban Blue Watch ~~$199†~~
Offer Code Price **$29** + S&P **Save $170**

★★★★★

"Are you kidding? What a great watch at a ridiculous price. Thank you Stauer!"
— Gitto, Hicksville NY

1-800-333-2045

Your Insider Offer Code: UBW490-02
You must use this insider offer code to get our special price.

† Special price only for customers using the offer code versus the price on Stauer.com without your offer code.

ACCREDITED BUSINESS BBB
Rating of **A+**

CONSUMER AFFAIRS ACCREDITED

Stauer®
14101 Southcross Drive W., Ste 155, Dept. UBW490-02
Burnsville, Minnesota 55337 www.stauer.com

- Precision movement • Stainless steel caseback and crown • Cotswold® mineral crystal
- Date window • Water resistant to 3 ATM • Genuine leather band fits wrists 6 ¾"–8 ¾"

THIS TIP HAS BRAGGING RIGHTS

The unique tip on our aerosol can mimics a professional spray gun for pro-like results. Compared to ordinary spray tips, its wide verticle fan pattern sprays easier and more evenly for that amazing pro-like finish you want, right out of the can. With over 300,000 factory and custom-mixed colors also available in ready-to-spray cans, paint pens, and brush-in-bottles, we're more than just a great tip.

AUTOMOTIVETOUCHUP
BASECOAT COLOR
Easy Application
Superior Formulation
Strong Coverage
Fast Drying

Automotivetouchup.com
888-710-5192

Own a Complete, Final-Year 1921

Morgan Dollar Collection

The Last Ever Minted!

Prized by collectors, genuine final-year Morgan Silver Dollars were struck in 1921 and never again.

Now, for a limited time, get all three for the special price of $99 – SAVE 55% off the regular price of $~~220.00~~ – with FREE shipping. Your complete hand-selected collection will arrive in a FREE custom presentation case showcasing the famous last-year 1921 Morgans from each United States Mint that struck them – Philadelphia, Denver and San Francisco! Each coin is encapsulated and preserved in an Air-Tite holder.

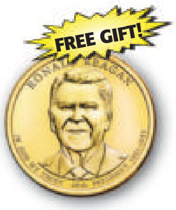
Take advantage of this limited-time offer to own these handsome silver coins from America's past – struck for the last time over 95 years ago and guaranteed authentic by Littleton Coin Company.

You'll also receive our fully illustrated catalog, plus other fascinating selections from our Free Examination Coins-on-Approval Service, from which you may purchase any or none of the coins – return balance in 15 days – with option to cancel at any time. *Order now and SAVE!*

SAVE 55% for a Limited Time!

Philadelphia Mint
Denver Mint
San Francisco Mint

FREE GIFT!



when you order within 30 days

Mail coupon or order online at www.LittletonCoin.com/specials

Due to fluctuations in the coin market, prices are subject to change.

©2020 LCC, Inc.

45-Day Money Back Guarantee of Satisfaction

Special Offer for New Customers Only

✓**YES!** Please send me the Complete Final-Year Morgan Dollar Set(s) indicated below for only $99 each – reg. $~~220.00~~, plus FREE shipping (limit 5 sets). Also send my FREE 2016 Ronald Reagan Presidential Dollar (1 per customer, please).

ORDERS MUST BE RECEIVED WITHIN 30 DAYS

QTY	DESCRIPTION	PRICE	TOTAL
	3-Coin Morgan Dollar Set *(limit 5 sets)*	$99.00	
	Sales Tax*		
FREE Shipping!	**TOTAL $**		

*We are required by law to collect and remit sales tax for all states except FL and MO. Please add the appropriate state and local tax for your order. For your convenience, all orders paid by credit card will have the appropriate sales tax applied at that time. *Tax requirements are subject to change at any time. Please visit LittletonCoin.com/TaxInfo for the most up-to-date list of taxable categories by state.*

☐ Check payable to Littleton Coin Co.

Charge my: ☐ VISA ☐ MasterCard ☐ American Express ☐ Discover

Card #: Exp. Date ☐☐/☐☐

Name ____________________

Please print clearly

Address ____________________ Apt# ______

City ____________________ State _____ Zip ________

E-Mail ____________________

Please send coupon to:

Littleton Coin Company®
Serving Collectors Since 1945

Dept. 5WT414
1309 Mt. Eustis Road
Littleton NH 03561-3737

With money left to buy lunch!

Get this with your money at a typical auto parts store.

Or ALL this at www.RockAuto.com!

ROCKAUTO.COM
ALL THE PARTS YOUR CAR WILL EVER NEED

✓ Reliably Low Prices
✓ Easy To Use Website
✓ Huge Selection
✓ Fast Shipping

Never lose electricity again!

Own the #1 brand in home standby power.

8 out of 10 buyers choose Generac Home Standby Generators to automatically provide electricity to their homes during power outages. GENERAC Home Standby Generators start at just $1,999.*

CALL for FREE Generator Buyer's Guide and…

Limited Time
BONUS OFFER!

GENERAC®

USA ENGINEERED & BUILT
*Built in the USA using domestic and foreign parts

TOLL FREE 877-200-7146
FreeGeneratorGuide.com
*Price does not include installation. 1B479X © 2020

THE NINE PLANETS RING

18K GOLD WITH A SPINNING METEORITE BAND AND GEMSTONE PLANETS

AVAILABLE IN TWO WIDTHS AND ANY SIZE. HANDMADE TO ORDER STARTING AT $3400

831.336.1020

NINEPLANETSRING.COM

ENJOY A CONTINUOUS SUPPLY OF HOT WATER FOR YOUR EVERY NEED.

WITH EZ 101

FREE SHIPPING
$164.95

219.369.4781 | EZTANKLESS.COM

Got Warts?

Electronic Wart Remover
Simple - Effective - Permanent
100% successful
(800) 645 0234
www.wartabater.com

SAVEUR
SELECTS®

TEXTURED
NON-SLIP
HANDLES

RIVET-LESS
INTERIOR

18/10 TRI-PLY
FULL-CLAD
STAINLESS STEEL

SAVEUR Selects® Voyage Series

SAVEURSELECTS.COM

WIDESHOES.COM

Men's Sizes 5-20 in 3E-8E

Hitchcock
wide shoes

Free Catalog!

600+ styles

800-992-WIDE

Hingham, MA 02043 • dept. PS2009

---

www.MAKEMYRECLINERALIFTCHAIR.com

NEW! Now you can convert your own favorite recliner into a Lift Chair (That should get a rise out of you!)

The easiest way to get up and GO!

The industry's only "Universal Lift Frame," attaching to the bottom of a favorite recliner to lift and tilt and ease you up like a traditional lift chair.

YOUR RECLINER with the MIRACLE LIFT

THE PERFECT LIFT CHAIR

1-888-217-1211

FREE

SOON Church/Government uniting, suppressing **"RELIGIOUS LIBERTY"** enforcing **"NATIONAL SUNDAY LAW."** Be Informed! Mailing address for **FREE MATERIALS.**
TBSM, PO Box 374, Ellijay, GA 30540
thebiblesaystruth@yahoo.com. 1-888-211-1715

GOLD/JEWELRY

GEAR RING &
GEAR NECKLACE

KINEKT.COM (888) 600-8494

POND & LAKE MANAGEMENT

Pre-Assembled
- Installs in Minutes!

1hp unit shown

CasCade 5000

Floating POND FOUNTAIN!
Aerator
Now Available Factory Direct!
MSRP *($1100)* You Pay *$798.95!*
Complete with light & timer,
100 ft power cord, 1yr warranty!
(Also available in 3/4hp &1.25hp)

Elegance & Improved Water Quality

Call 7days/week! **FAST UPS shipping right to your door!**
(608) 254-2735 **www.fishpondaerator.com**

DO YOU HAVE A PRODUCT OR BUSINESS?

To advertise in *Popular Science* magazine, contact:

Chip Parham 212.779.5492
chip.parham@bonniercorp.com

» **popsci.com** «

H2O

Scams Exposed!

FREE Report 15^{00} value

Discover the truth about distilled, mineral, tap, spring, filtered, bottled, well, alkalized, reverse osmosis and more...

Which one is best for you?

www.waterscamsexposed.com

—or call for FREE Report & Catalog

Waterwise Inc
PO Box 494000 Leesburg FL 34749

800-874-9028 Ext 781

ATHENA PHEROMONES™

INCREASE AFFECTION

Created by Winnifred Cutler, Ph.D. in biology from U. of Penn, post-doc Stanford. Co-discovered human pheromones in 1986 *(Time 12/1/86; and Newsweek 1/12/87)*

SAVE $100: 6-Pak Special Offer

PROVEN EFFECTIVE IN 3 DOUBLE-BLIND STUDIES

Unscented
Fragrance
Additives

ATHENA PHEROMONES™
increase your attractiveness.
Athena 10X™ For Men $99.50
10:13™ For Women $98.50
Cosmetics Free U.S. Shipping

♥ **Bob (FL)** 10X reorder "Your scientific 'magic trick' does seem to work. **I give 10X credit as one of the things I did that helped save my marriage. Thanks."**

♥ **Ken (WA)** **"My wife likes me better when I wear 10X.** I know the difference between men and women. I know men are simple. Switch on or off. Women, dials rheostats gauges. Much more complex. **But when I wear the 10X it dials in and it is all tuned. She wants to be with me."**

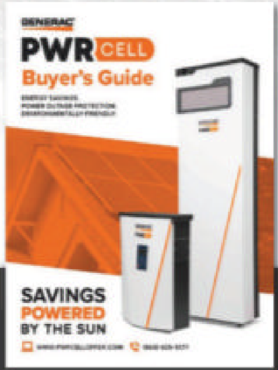
Not in stores 610-827-2200
Athenainstitute.com
Athena Institute, Braefield Rd, Chester Spgs, PA 19425 PS

Save More with Generac

GENERAC
PWRCELL
SOLAR + BATTERY STORAGE SYSTEM

Power your home, reduce your electric bill and be prepared for power outages with the Generac PWRcell, a fully integrated solar + battery storage system.

Learn more today!

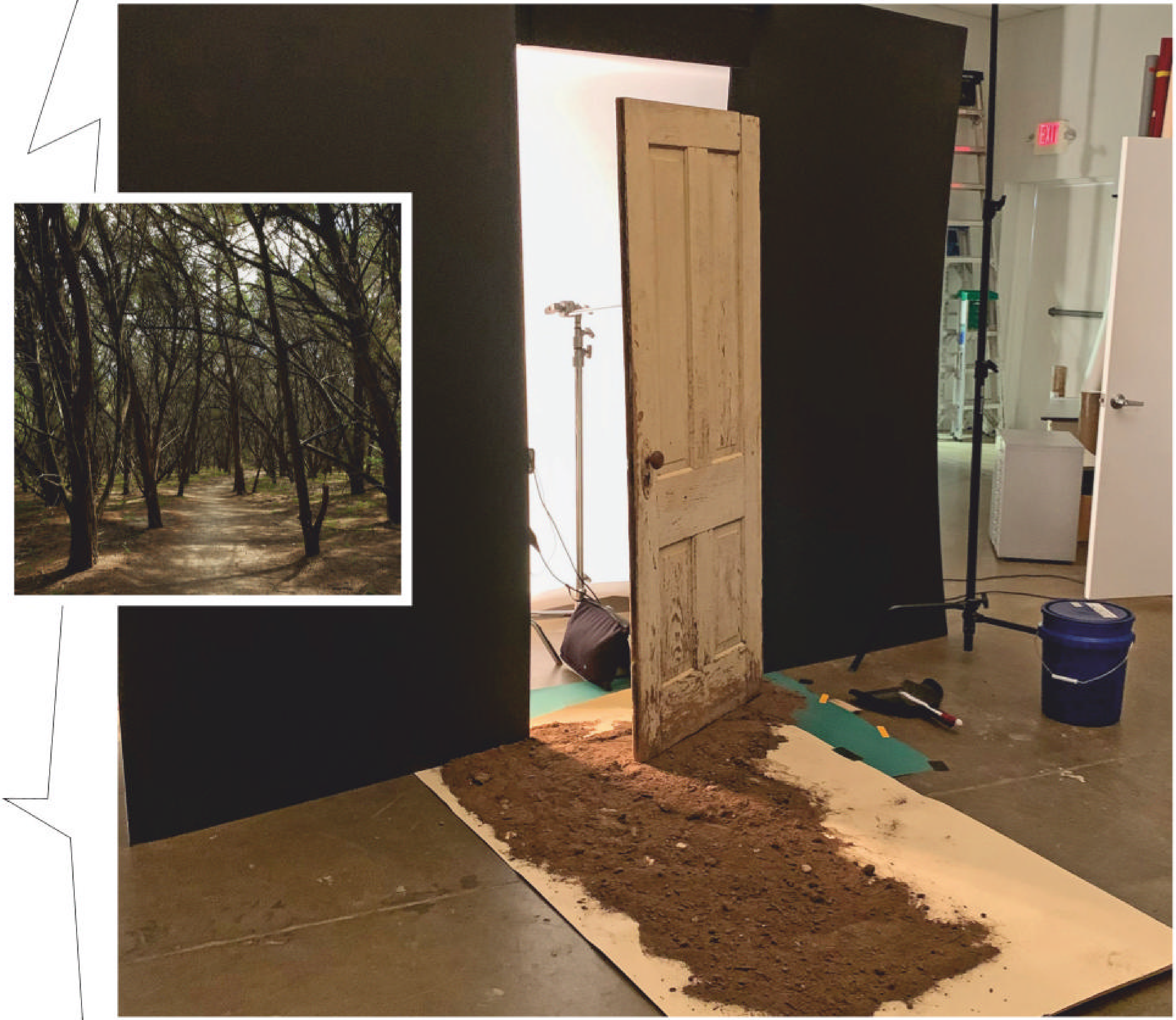


Request your FREE copy of the PWRcell Buyer's Guide today!

PWRcellGuide.com | (855) 586-0678

BEHIND THE COVER

BY *SARA KILEY WATSON* / PHOTOGRAPHS BY *THE VOORHES*



• The forest on the cover is a real place, but it's not as eerie as it looks. Adam Voorhes, of photography duo The Voorhes, captured it in Stephenson Nature Reserve in Austin, Texas, where he ventured to find the perfect backdrop.

Before pressing the shutter, he waited for enough cloud cover to generate a soft, diffused light that could transform the sunny hiking spot into an otherworldly scene. Adam, together with partner and producer Robin Finlay, overlaid the image with some digital smoke and a shot of a white vintage door taken inside their studio. The spooky result is a bright portal leading somewhere beyond the imagination.

No matter how much you look, you won't find this particular threshold to the unknown. If while walking in the woods you stumble upon another one, well, that's a whole other mystery.

Please Recycle This Magazine
Remove Inserts or Samples Before Recycling

POPULAR SCIENCE magazine, Vol. 292, No. 3 (ISSN 161-7370, USPS 577-250), is published quarterly by Bonnier Corp., 480 North Orlando Ave., Suite 236, Winter Park, FL 32789. Copyright ©2020 by Bonnier Corp. All rights reserved. Reprinting in whole or part is forbidden except by permission of Bonnier Corp. POSTMASTER: Send address changes to POPULAR SCIENCE, P.O. Box 6364, Harlan, IA 51593-1864. Periodicals postage paid at Winter Park, FL, and additional mailing offices. Subscription Rates: $25 for one year for US addresses; $35 for one year for Canadian addresses; $45 for one year for all other international addresses. Canada Post Publications agreement No. 40612608. Canada Return Mail: IMEX Global Solutions, P.O. Box 25542, London, ON N6C 6B2. Printed in the USA. Subscriptions processed electronically. Subscribers: If the post office alerts us that your magazine is undeliverable, we have no further obligation unless we receive a corrected address within two years. Photocopy Permission: Permission is granted by POPULAR SCIENCE for libraries and others registered with the Copyright Clearance Center (CCC) to photocopy articles in this issue for the flat fee of $1 per copy of each article or any part of an article. Send correspondence and payment to CCC (21 Congress St., Salem, MA 01970); specify CCC code 0161-7370/85/$1.00-0.00. Copying done for other than personal or reference use without the written permission of POPULAR SCIENCE is prohibited. Send requests for permission on bulk orders to reprints@bonniercorp.com. Editorial offices: Send contributions to queries@popsci.com. We are not responsible for loss of unsolicited materials. Microfilm editions are available from Xerox University Microfilms Serial Bid Coordinator, 300 N. Zeeb Rd., Ann Arbor, MI 48106.

SURGEON GENERAL'S WARNING: Cigarette Smoke Contains Carbon Monoxide.

NEW

MADE WITH 100% PLANT BASED MENTHOL*

Winston
100% PLANT-BASED MENTHOL
GREEN BOX

PREMIUM TOBACCO.
PLANT-BASED MENTHOL.
ENOUGH SAID.

GRAB A COUPON & GIVE 'EM A TRY AT
WINSTONCIGARETTES.COM/SCIENCE

WINSTON® IS A REGISTERED TRADEMARK OF ITG BRANDS, LLC.
©2020 ITG BRANDS, LLC

*THESE CIGARETTES DO NOT PRESENT A REDUCED RISK OF HARM COMPARED TO OTHER CIGARETTES